Hydrogeological Assessment, Conservation Meadows Subdivision, Phase 2, Waterloo, Ontario

VERSION 2

60308671

December 2019

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Sign-off Sheet

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Abbreviations

AMSL	above mean sea level
ASTM	American Society for Testing and Materials
BGS	below ground surface
City	City of Waterloo
EASR	Environmental Activity Sector Registry
GRCA	Grand River Conservation Area
GRIN	Grand River Information Network
DNAPL	dense non-aqueous phase liquid
IMAC	Interim Maximum Acceptable Criteria
LID	Low Impact Development
MAC	Maximum Acceptable Criteria
ODWS	Ontario Drinking Water Quality Standards
OG	Operational Guideline
PSW	Provincially Significant Wetland
PTTW	Permit to Take Water
RMOW	Regional Municipality of Waterloo
Site	Conservation Meadows Subdivision, located on Part Lot 28, German Company Tract, City of Waterloo
SGRA	Significant Groundwater Recharge Area
Stantec	Stantec Consulting Ltd.
WHPA	Well Head Protection Area

1.0 INTRODUCTION

Activa Holdings Inc. (Activa) retained Stantec Consulting Limited (Stantec) to complete a hydrogeological assessment for Phase 2 of the Conservation Meadows Subdivision, located on Part Lot 28, German Company Tract, City of Waterloo (Site) in support of Zone Change and Draft Plan approvals. Stantec issued the first version of this Hydrogeological Assessment Report in September 2017. This revised version of the report considers changes made to the Draft Plan since that time and addresses hydrogeological related comments provided by the following agencies:

- *Grand River Conservation Authority (GRCA), Letter dated November 22, 2017 Re: Draft Plan of Subdivision 30T-17403 and Zone Change Application Z-17-14, Conservation Meadows Phase 2, Activa Holdings Inc. / MHBC Planning*
- *Region of Waterloo, Letter dated February 9, 2018 Re: Post Circulation Comments, Subdivision Plan 30T-17403, Zoning By-law Amendment Application Z-17-20, Activa Holdings Inc. / MHBC Planning, n/s Conservation Dr., w/s and e/s Rideau River St., City of Waterloo*
- *City of Waterloo, Letter dated February 13, 2018 Re: Post Circulation Comments, Zone Change Application Z-17-20 and Subdivision Application 30T-17403 (Activa Holdings Inc.)*

The Site covers an area of approximately 8.0 hectares and is bounded by Conservation Drive to the south, Roy Schmidt Road to the west, existing Phase 1 residential area to the north, and existing residential area to the east (Figure 1). The Site resides within the North Waterloo Scoped Subwatershed Study (NWSSS) area (Ecoplans Ltd *et al.*, 2013), with Stantec utilizing information provided in this study together with data collected from historical onsite geotechnical and groundwater monitoring investigations to meet the following hydrogeological assessment objectives:

1. Characterize the existing geological and hydrogeological conditions within the Site, including the identification of groundwater depths and flow patterns, groundwater quality conditions and potential hydraulic relationships between local aquifer systems and surface water features.
2. Assess whether residential foundations and water/sewage servicing will intercept the groundwater table and determine what mitigation measures could be employed to minimize the potential disturbances on pre-development groundwater elevations and flow patterns.
3. Assess the potential need for construction dewatering throughout the various construction phases of the development and discuss potential mitigation measures if dewatering is required.
4. Review the pre- and post-development water balance to confirm that they conform to the requirements of the NWSSS; that is, evaluate potential land use change impacts to the groundwater recharge function of the Site, including an evaluation of proposed measures to be employed under the post-development condition to mitigate these impacts.
5. Review the proposed land use activities for conformity with Source Water Protection requirements as stipulated in the Clean Water Act, 2006, S.O. 2006, c. 22.

6. Recommend an on-going groundwater monitoring program that adheres to the specifications outlined in the NWSSS (Ecoplans et al., 2013).

This report is arranged into eight sections, including this introduction (Section 1). Section 2 presents the physical site setting. Section 3 explains the additional geotechnical and hydrogeological work that has been completed on the Site since the issuing of the initial report, with local geological and hydrogeological conditions for the Site being discussed in Section 4. Section 5 presents an assessment of the potential impacts to the hydrogeological form and function of the Site from the proposed development. Section 6 provides recommendations for the implementation of a pre-, during- and post-construction groundwater monitoring program. Report conclusions are listed in Section 7, with references being provided in Section 8.

All figures and tables referenced in this report are presented in Appendices A and B, respectively. Appendices C to F present the Borehole Logs, Hydraulic Conductivity Analytical Solutions, Grand River Information Network (GRIN) Mapping, and Dewatering Calculations, respectively.



2.0 PHYSICAL SETTING

2.1 PHYSIOGRAPHY, TOPOGRAPHY AND DRAINAGE

The Site is situated along the border of the Oxford Till Plain and Waterloo Hills physiographic regions (Figure 2). As defined by Chapman and Putnam (1984), the Oxford Till Plain is a drumlinized till plain characterized by undulating to gently rolling topography and soils of a calcareous nature. The Waterloo Hills (also commonly referred to as the Waterloo Moraine) occupies a large portion of the Regional Municipality of Waterloo, with the surface of this physiographic feature consisting of sandy hills, ridges of sandy till, kames or kame moraines and intervening hollows of outwash sand and gravel, which all can be capped by glacial till.

The Site is relatively steep, with elevations ranging from approximately 353.5 m AMSL at Conservation Drive to 364.0 m AMSL at the north end of the proposed development area (Figure 3). Average grades generally range from three to five percent across the Site, with steeper grades occurring closer to Conservation Drive.

An east-west high topographic ridge divides the Site from the existing residential development to the north, where runoff from this point of the Site drains south towards Conservation Drive and into the North Waterloo Subwatershed. A topographic high point of approximately 357.4 m AMSL occurs along Conservation Drive at the intersection of this roadway at Rideau River Street, with the grade sloping to the southwest to a low point at Kawartha Street where runoff spills to the south onto the lands occupied by Green Acre Park. Ultimately, this runoff flows south and discharges to the Laurel Creek Reservoir (Figure 2).

Land cover at the Site currently consists of a mixture of agricultural cropland and areas of meadow vegetation previously disturbed by construction activity.

2.2 SURFACE WATER BODIES AND WETLANDS

No surface waterbodies or wetlands occur within the boundaries of the Site. The nearest surface water features to the Site include Beaver Creek and Laurel Creek, which are located approximately 500 m and 700 m to the south-southwest of the Site, respectively. These two creeks flow south into the Laurel Creek Reservoir before flowing east to the Grand River, which is located approximately 8.25 km away from the Site. The Sunfish Lake and Laurel Creek Wetland Complex is a provincially significant wetland (PSW) associated with the two creeks and reservoir (Figure 2).

The Grand River Conservation Authority (GRCA) (1993, as cited in Ecoplans et al., 2013) classified the reach of Laurel Creek located to the south of the Site as a coldwater system and an important source of groundwater discharge that supplies baseflow to the creek and PSW. This classification was confirmed as part of the NWSSS, where stream flow and vertical hydraulic gradient data indicated the presence of



groundwater discharge conditions along Laurel Creek during both high and low groundwater level conditions (Ecoplans *et al.*, 2013).

Beaver Creek is a potential coldwater system, but its function as a groundwater discharge area has been degraded over the years by intensive agricultural activity in the subwatershed. Minimal groundwater-surface water interactions were interpreted along the majority of Beaver Creek in the NWSSS, except for seasonal groundwater discharge along the southern extents of this watercourse (Ecoplans *et al.*, 2013).

2.3 REGIONAL GEOLOGY AND HYDROGEOLOGY

The Site is located within the Waterloo Moraine, a kame moraine formed in an interlobate position between ice lobes extending from the Lake Ontario-Erie, Huron, and Georgian bay areas (Karrow, 1993). Numerous advances and retreats of the ice lobes during the Wisconsinan glaciation resulted in a complex deposit of ice-contact and glacial outwash sands and gravels separated by silt- and clay-rich tills. The conceptual hydrogeologic model for the Waterloo Moraine comprises four main aquifers and aquitards after Terraqua Investigations Ltd (1995), which was broken down further into 19 hydrostratigraphic units after Bajc and Shirota (2007). The model generally does not include more recent deposits shown on surficial geology mapping such as organics (Unit 20, Figure 4) or modern alluvium (Unit 19, Figure 4), which are found in wetlands and creek/river valleys.

The three regionally based hydrostratigraphic units generally encountered in the area containing the Site, and at depths associated with the current investigation, are described below. The units are described from ground surface downward, with Bajc and Shirota (2007) unit names shown in parentheses.

Aquitard 1 (ATB1): Surficial and spatially discontinuous glacial till unit, which along the eastern flank of the Moraine consists of the Upper Maryhill Till (clayey silt to silty clay) (Bajc and Shirota, 2007). Aquitard 1 is characterized by low permeability and forms a relatively impermeable barrier that effectively limits the downward movement of surface water to the deeper aquifer systems. Perched groundwater conditions are commonly encountered within this unit.

Aquifer 1 (AFB1/ATB2/AFB2): This hydrostratigraphic unit represents the main water supply aquifer in the core areas of the Waterloo Moraine. Depending on the depositional environment, the composition of Aquifer 1 varies from a layered silt and fine sand to coarse sand and gravel (Unit 6 and Unit 7a, Figure 3). Throughout the core areas of the moraine, Aquifer 1 corresponds to a thick, laterally extensive sand and/or gravel aquifer overlying Aquitard 2 and is often exposed at surface in the core areas of the moraine. In some areas, Aquifer 1 is interpreted to be bisected by the Middle Maryhill Till (ATB2), effectively separating Aquifer 1 into two units, AFB1 and AFB2. Along the flanks of the Moraine, Aquifer 1 generally thins as the ground surface elevation decreases and approaches Aquitard 2.

Aquitard 2 (ATB3): Aquitard 2 corresponds to the lower Maryhill Till and represents one of the primary regional hydrostratigraphic units. The Maryhill Till was broken down into Upper (ATB1), Middle (ATB2) and Lower (ATB3) units by Bajc and Shirota (2007). Along the flanks of the moraine, the Maryhill Till is often found to be discontinuous or has been re-worked and re-deposited as glaciofluvial sediments. ATB3 is present throughout most of the North Waterloo Subwatershed, except for localized areas where it has been eroded by glacial meltwater channels.

As noted in the NWSSS (Ecoplans et al., 2013), regional groundwater flow is from west to east across the core of the Moraine. Within the North Waterloo Subwatershed, shallow groundwater flow converges on Laurel Creek and its associated features.

2.4 SOURCE WATER PROTECTION

The Site intersects Well Head Protection Area (WHPA) C and D for Waterloo North Production Well W5A (Figure 5). WHPA-C and WHPA-D represent the areas in which the time-of-travel for a potential contaminant from surface to the municipal production well is between two and 10 years, and 10 and 25 years, respectively. The Site is also shown to intersect a Significant Groundwater Recharge Area (SGRA) at its southeast corner (Figure 6), coinciding with an area mapped as ice-contact stratified drift (Unit 6, Figure 4), which is interpreted to be associated with Aquifer 1. However, Stantec notes that drilling in this area of the Site indicates that the surficial soils consist of fill underlain by native deposits of silt, silty clay and silt till, which are interpreted to represent Aquitard 1 (see Section 4.1).

Under the Approved Source Protection Plan for the Grand River Source Protection Area, significant drinking water quality threats are defined within the WHPA-C for Waterloo North Production Well W5A for activities related to handling and storage of a dense non-aqueous phase liquid (DNAPL) (Lake Erie Region Source Protection Committee, 2015). Preliminary screening through the Regional Municipality of Waterloo (RMOW) TAPS Source Water Protection Tool (2017) will be required as part of the planning approval application process.

Additionally, the Site intersects a Wellhead Protection Sensitivity Area 8 (WPSA-8), as defined per the Official Plan 2031 (RMOW, 2015). The WPSA-8 “delineates the area outside the 10 year time-of-travel to the limit of the total land area contributing water to a municipal drinking water supply well” (RMOW, 2015). Within the WPSA-8, Category A or “High Risk Uses” per Schedule B of the Official Plan 2031 are not permitted (i.e., waste treatment and disposal facilities, salvage yards and bulk storage or hazardous chemicals or substances). The proposed development will not include any Category A land uses. Development will not be impacted by Source Water Protection policies under the Official Plan 2031.

3.0 METHODOLOGY

Since the initial submission of this hydrogeological report, additional geotechnical and hydrogeological field work has occurred at the Site, including:

- drilling of boreholes and excavation of test pits
- installing of monitoring wells
- monitoring of groundwater levels
- performing of hydraulic response (hydraulic conductivity) testing

A description of the methods to complete these tasks is described in Sections 3.2 to 3.5 below.

3.1 HISTORICAL INVESTIGATIONS

In December 2002, Naylor Engineering Associates (Naylor) completed a geotechnical field investigation of the Phase 1 and 2 areas of the Site, which involved the drilling of 21 boreholes (BH1 to BH21) and excavation of 34 test pits (TP1 to TP34) (Naylor Engineering Associates, 2003). In 2007, Naylor returned to the Site and drilled an additional five boreholes (BH101 to BH105), equipping each borehole with a groundwater monitoring well. As shown in Figure 1, BH104, BH105 and BH12 (also equipped with a monitoring well) are located within, or immediately adjacent to, the Site. Copies of the corresponding borehole logs are provided in Appendix C.

As part of the NWSSS (Ecoplans et al., 2013), Stantec observed the installation of 17 monitoring wells throughout the NWSSS investigation area. One of these monitoring wells (i.e., MW7-10) is constructed outside the western limits of the Site directly adjacent to Roy Schmidt Road (Figure 1). The continuous monitoring of groundwater levels in this well for the NWSSS has been ongoing since March 2010. A copy of the borehole log for MW7-10 is provided in Appendix C.

3.2 BOREHOLE DRILLING AND TEST PIT EXCAVATIONS

From January 17 to 18, 2019 boreholes were advanced at seven locations across the Site (Figure 1) using a track-mounted drilling rig equipped with solid-stem augers operated by a licensed drilling subcontractor. The depth of the boreholes extended to 3.0 m to 7.6 m below ground surface (BGS), with each borehole being equipped with a single monitoring well (i.e., MW01-18 to MW07-18). Soil sampling occurred using a 0.6 m long stainless steel split spoon sampler at 0.76 m to 1.52 m intervals to the termination depth of the borehole using a 51 mm (outside diameter) split-tube sampler. The soil sampling included the performing of Standard Penetration Tests (SPTs) as per the procedures outlined in ASTM (2011) specification D1586. Stantec personnel directed the drilling and soil sampling operations and logged the borehole stratigraphy. The borehole logs contain descriptions (where relevant and possible) of soil type, texture, colour, structure, consistency, plasticity, moisture content, and other visual and olfactory

observations as per the procedures outlined in ASTM (2009) specification D2488-09a. Overall, the boreholes were strategically positioned throughout the southern extents of the Site to confirm shallow soil conditions and seasonal groundwater depths to assist in the design of residential, servicing and Low Impact Development (LID) stormwater management structures. Copies of the borehole logs are provided in Appendix C.

In March 2018, Stantec supervised the excavation of nine test pits (TP01-18 to TP07-18) throughout the Site, with the test pits being completed using a rubber-tired backhoe excavator operated by an excavating subcontractor (Figure 1). Test pit excavations extended to depths from 1.2 m to 2.6 m below existing grades for the purpose of evaluating shallow soil and groundwater conditions to provide recommendations for pavement design (Stantec, 2019a).

3.3 MONITORING WELL INSTALLATION AND DEVELOPMENT

Stantec observed the installation of monitoring wells in the seven boreholes advanced at the Site (i.e., MW01-18 to MW07-18). The monitoring well installations were completed between January 17 and 18, 2018 to allow for the measurement of groundwater levels and the completion of other hydrogeological testing. The drilling subcontractor constructed the monitoring wells to specifications outlined under Ontario Regulation 903 (O. Reg. 903) (MOE, 1990), consisting of 50 mm inside diameter, Schedule 40 polyvinyl chloride (PVC) pipe, with No. 10 slot screen (0.01-inch slot) measuring 1.5 m in length. Silica sand was used to backfill the screened interval to heights ranging from 0.3 to 0.5 m above the top of screen, followed by granular bentonite to existing grades to prevent a hydraulic connection from occurring between the screened formation and overlying soils. The completion of each monitoring well involved encasing the pipe stick-up within a lockable steel casing. Stantec Geomatics completed a geodetic survey of the Universal Transverse Mercator (UTM) coordinates and top-of-pipe elevation of each monitoring well. The well construction details, coordinates and elevation data obtained from the geodetic survey are presented in Table 1 and summarized on the borehole logs provided in Appendix C.

Following installation, Stantec personnel developed the seven monitoring wells. The purpose of developing the monitoring wells is to remove drilling fluids, solids or other particulates that may have been introduced during drilling. Stantec personnel purged each monitoring well using dedicated 16 mm inside diameter high density polyethylene (HDPE) tubing connected to a D-25 Waterra™ foot valve. Where possible, Stantec personnel purged a minimum of six standing column volumes from the well to clear out any fine-grained sediments and, subsequently, establish a proper hydraulic connection with the native aquifer material.

3.4 GROUNDWATER LEVEL MONITORING

Stantec personnel obtained manual groundwater level measurements from BH12, MW01-18 to MW07-18, BH104 and BH105 on an approximately monthly basis from February 2018 to July 2019. The measurements were recorded in meters to the nearest 0.01 m using a battery-operated water level indicator. Manual water levels collected from the monitoring wells are presented in Table 2. Hydrographs presenting the manually measured groundwater levels collected from MW01-18 to MW07-18 is provided

in Figure 7. Hydrographs showing historical measurements recorded at BH12, BH102 to BH105, and MW7-10 is presented in Figure 8.

3.5 HYDRAULIC RESPONSE TESTING

To estimate the horizontal hydraulic conductivity of the deposits beneath the Site, Stantec performed in- situ hydraulic response testing on MW01-18 to MW04-18 and MW06-18 on May 25, 2019. The testing completed on MW7-10 occurred as part of the NWSSS (Ecoplans et al., 2013). The testing performed for this investigation consisted of creating an instantaneous change in the monitoring well water level by removing a known volume of water from the well (i.e., rising head / bail test), followed by recording the time taken for the resulting water level to return to static conditions using a combination manual and continuous (i.e., datalogger) measurements. The testing results were analyzed using the Bouwer and Rice (1976) / Bouwer (1989) solution provided in the software package AQTESOLV™ Pro Version 4.5 (Duffield, 2014) to calculate the horizontal hydraulic conductivity of the aquifer sediments within the immediate vicinity of the screened interval of each monitoring well. Table 1 provides a summary of the calculated horizontal hydraulic conductivities, with the analytical solutions for the data being presented in Appendix D.

4.0 LOCAL GEOLOGY AND HYDROGEOLOGY

4.1 GEOLOGY AND HYDROSTRATIGRAPHY

Figure 4 presents the surficial geological conditions within the Site and surrounding area as mapped by the OGS (2003) and the locations of Cross Sections A-A' (Figure 9), B-B' (Figure 10), and C-C' (Figure 11). These cross-sections were constructed using historical borehole information and the results of onsite drilling investigations recently completed by Stantec. A summary of these drilling results is shown on the borehole logs provided in Appendix C. As shown in Figure 4, the Site is largely covered by glaciolacustrine-derived deposits of silt, clayey silt, and silt-textured till, with these deposits being interpreted to represent the Upper Maryhill Till of Aquitard 1 (ATB1). Results of the onsite drilling investigation indicate that most of the Site is covered by a 1.4 m to 2.3 m layer of silty to sandy fill, except at MW07-18 where the fill material extends from the existing grade to a depth of 5.2 m BGS (Figure 9), with these deposits in turn overlie Aquitard 1 (ATB1). Aquitard 1 ranges from 0.8 m to 4.7 m thick and extends horizontally throughout the subsurface of the Site, except in those areas near MW05-18 and MW07-18 where sand to silty sand deposits (interpreted to represent the silt to sand deposits of Aquifer 1 (AFB1)) come directly into contact with the overlying fill (Figure 10). Sand to silty sand layers ranging from 1.2 m to 1.6 m thick are also found to be occasionally interspersed within Aquitard 1 (ATB1) (e.g., MW04-18 and MW7-10; Figures 9 and 11).

4.2 HYDROGEOLOGY

4.2.1 Groundwater Levels

Table 2 provides a summary of the manual groundwater level measurements obtained from MW01-18 to MW07-18, BH104 and BH105 between February 2018 and July 2019. Hydrographs presenting the results of the groundwater level monitoring, including historical readings taken from BH104, BH105 and MW7-10 prior to 2018, are presented in Figures 7 and 8.

Historical high groundwater elevations recorded at each of the previously mentioned monitoring wells is presented on Figure 3. Overall, the high groundwater table tends to be positioned at elevations ranging from 354.13 to 354.68 m AMSL in the south half of the Site, equating to depths of less than 0.1 m BGS (MW04-18) to 6.8 m BGS (MW05-18) based on existing grades. The groundwater tends to be shallowest in areas closest to Conservation Drive, with groundwater depths becoming progressively deeper moving to the north across the Site. For example, at the northern limits of the Site, the high groundwater table is found to be positioned at a depth of 7.1 m BGS (BH104).

The high groundwater level observed at MW03-18 (i.e., 356.41 m ASML) is likely a function of the low permeability soil of Aquitard 1 encountered in the western portion of the Site. Due to the characteristically low hydraulic conductivity of Aquitard 1, a high hydraulic gradient is required to facilitate the horizontal movement of groundwater through these deposits and, subsequently, a steep hydraulic gradient is shown

to occur within the southwestern portion of the Site (Figure 3). Recognizing the heterogeneity of the onsite soils, isolated pockets of elevated groundwater levels may be encountered in those areas of the Site where the Upper Maryhill Till of Aquitard 1 predominates. Given that the unusually high groundwater level observed at MW03-18 (compared to other nearby onsite monitoring wells) appears to be a localized condition, this location was subsequently excluded from the data set used to construct the high groundwater elevation mapping (Figure 3).

Groundwater level data obtained from MW07-18 was also not used in the developing of the high groundwater elevation mapping presented in Figure 3. As depicted in Figure 9, groundwater appears to become seasonally perched at the base of the fill material (i.e., following the spring melt in March/April), resulting in anomalous readings when compared to groundwater elevations observed in surrounding monitoring wells (i.e., BH104 and BH105). Overall, this monitoring well is shown to be mostly dry throughout a given year, with groundwater elevations being less than 355.47 m AMSL (i.e., the base elevation of the monitoring well) (Table 2).

Annual groundwater level fluctuations of 0.3 m to 2.0 m are noted on the hydrographs (Figures 7 and 8), with the highest elevations occurring in the early spring, followed by gradual declines over the summer and into the early fall. This pattern in fluctuations is common within shallow groundwater systems in southern Ontario, where high groundwater table conditions occur in the spring as a result of lower evapotranspiration losses and a melting snowpack, providing a greater volume of water for infiltration and the recharging of the groundwater system. Low groundwater table conditions occur in the late summer to fall as more water is pulled out of the subsurface over this period to meet evapotranspiration demands.

4.2.2 Groundwater Flow

The high groundwater elevations presented on Figure 3 represent measurements obtained in May 2019, except for the elevation at BH104, which was recorded in March 2015. Stantec used these groundwater measurements to construct elevation contours, which indicate that groundwater horizontally flows in a south and south-southwest direction across the Site towards Conservation Drive.

Based on the groundwater elevation contours presented in Figure 3, groundwater is interpreted to flow across the Site at an average horizontal hydraulic gradient of 0.01 m/m, as measured between the northern and southern boundaries of the property. The bulk horizontal hydraulic conductivity for the subsurface deposits is calculated to be 3.1×10^{-6} m/s (Table 1). This value is consistent with the upper limit of hydraulic conductivity cited for clayey sands, sandy silts and till of 10^{-6} m/s to 10^{-8} m/s, after Fetter (2001). Applying Darcy's law:

$$v = \frac{K \nabla}{\theta}$$

where: v = velocity (m/yr)
K = hydraulic conductivity (3.1×10^{-6} m/s)
∇ = hydraulic gradient (0.01 m/m)
θ = porosity (0.35 for mixed/silty sand to silt, after Fetter 2001)

The estimated average velocity of horizontal groundwater flow through the subsurface of the Site is calculated to be approximately 2.8 m per year.

Data available on the Grand River Information Network (GRIN, 2019) indicates that downward vertical hydraulic gradients occur beneath the entire Site, suggesting that these lands represent a groundwater recharge area; however, the recharge potential of the Site is relatively low with rates being reported to range from 50 mm to 100 mm/year (Appendix E). The groundwater recharge function of the Site is likely limited due to the presence of low permeability clay to silt textured fill and glaciolacustrine deposits at surface. Groundwater flow from the Site, however limited, may ultimately contribute to groundwater discharge (baseflow) to Laurel Creek, Beaver Creek and the Sunfish Lake and Laurel Creek Wetland Complex.

4.2.3 Groundwater Quality

Groundwater quality sampling was completed by Stantec at MW7-10 from 2010 to 2015 (as part of the NWSSS) for general chemistry and dissolved metals analysis. Analytic results were reported in Stantec (2016) and are provided in Table 3 (Appendix B) for reference.

Groundwater quality data at MW7-10 were assessed against Ontario Regulation 169/03, the Ontario Drinking Water Quality Standards (ODWS). Data show no exceedances of health-related ODWS criteria; that is, Maximum Acceptable Criteria (MAC) and Interim Maximum Acceptable Criteria (IMAC) for the tested parameters. However, the non-health related Operational Guideline (OG) for hardness (80-100 mg/L) was consistently exceeded. The presence of elevated hardness is not unexpected, given the calcareous nature of the local soils, and is quite common through the Waterloo area. Based on the anion to cation ratio of the analytical samples, groundwater at MW7-10 can be classified as calcium-bicarbonate type water.

5.0 IMPACT ASSESSMENT

5.1 WATER BALANCE AND INFILTRATION

A water balance analysis was completed as part of the NWSSS for the 31.8 ha subcatchment of the North Waterloo Subwatershed that includes the Site (Ecoplans et al., 2013). The analysis was based on the results of a hydrological model developed for the North Waterloo Subwatershed with the GAWSER modelling software. The analysis made use of regional inputs such as soils, land use, and topography, and local inputs such as meteorological data from the Laurel Dam weather station, and stream flow data from Beaver and Laurel creeks. As documented and discussed in the Stantec (2019b) *Conservation Meadows Subdivision - Phase 2, Functional Servicing and Stormwater Management Report*, the GAWSER model was rerun using updated hydrologic parameters for the Site based on the proposed Draft Plan to evaluate monthly pre- to post-development infiltration volumes and develop a preliminary Low Impact Development (LID) stormwater management strategy to offset predicted annual infiltration losses.

Low impact development (LID) is a stormwater management strategy that seeks to mitigate the impacts of increased stormwater runoff by managing this runoff as close to source as possible, with the implementation of such strategies also providing the residual benefit of offsetting potential infiltration losses associated with the increase in impervious surfaces associated with a given development. For the Site, Stantec is proposing to capture runoff generated from all rooftop areas and direct this water to a series of onsite infiltration trenches, with the preliminary locations of these trenches being shown on Figure 1. Details on the infiltration trench sizing, depths and other associated design parameters are discussed in Stantec (2019b), noting that the trenches are designed based on a conservative soil infiltration rate of 4 mm/hour (to account for silt, clayey silt, and silt-textured till deposits encountered at the Site) together with the trenches being upsized by 15% per Region of Waterloo requirements to account for the long-term degradation of the trench performance.

As shown in Figures 9 to 11, existing grades throughout the Site will be raised to account for the high groundwater table condition and permit the base elevation of the proposed infiltration trenches to remain above the groundwater table and, subsequently, allow for these LID structures to function as designed.

5.2 GROUNDWATER DEWATERING

5.2.1 Quantity

The proposed development will be connected to underground utility infrastructure (e.g., storm and sanitary sewers). The proposed location of this infrastructure is provided on Figure 1, with selected examples of where the sanitary and storm sewers will occur in the subsurface relative to the high groundwater table being provided on Figures 9 to 11. Based on the invert elevations of the proposed



storm and sanitary servicing, Stantec anticipates that excavation of the trenches required to install this servicing will extend near to, or intercept, the water table, particularly in the southern extents of the Site.

Stantec utilized the Dupuit-Forchheimer equation (Powers *et al.*, 2007) to estimate what volume of dewatering could be required to lower groundwater elevations throughout the Site to install the previously mentioned servicing. A conservative estimate of the maximum day pumping rates are calculated using a derivation of the equation, which assumes that flow is discharging into the trench from each side of the excavation and at each end of the trench (i.e., ends treated as one half of a circular well with radial flow). The input parameters required for this equation were taken from the findings of the onsite hydrogeological investigation and included information such as the expected length of the trench to be open at one time during construction, horizontal hydraulic conductivity of the subsurface material, the base elevation of the aquifer being pumped, the high groundwater elevation, and the targeted groundwater dewatering elevation. The calculated groundwater dewatering volumes are based on the following assumptions:

- The length of servicing trench open at one time will be 100 m.
- The water table surface resides within deposits of fine to medium sand, silty sand, clayey silt, and silt-textured till that underlie the Site, which is characterized by horizontal conductivities ranging from 8.7×10^{-5} m/s (sand) to 6.0×10^{-8} m/s (silt, clay). The calculated bulk horizontal hydraulic conductivity for the shallow overburden is 3.1×10^{-6} m/s, representing the geometric mean of the above field-tested hydraulic conductivities. For the purposes of the dewatering calculations, Stantec used the highest calculated hydraulic conductivity of 3.3×10^{-5} m/s. Stantec notes that the use of this value assumes that fine to medium-grained deposts of sand form the entire subsurface of the Site (i.e., ignoring the low permeability deposits of clayey silt and silt till), lending to the conservative nature of the analysis.
- The highest groundwater elevation recorded in onsite monitoring wells located closest to the proposed servicing infrastructure were used in the dewatering calculations. Depending on the location evaluated, groundwater elevations ranged from 352.9 to 354.7 m AMSL.
- The depth of dewatering is set to 0.5 m below the invert elevation of the sanitary or storm sewer pipe.
- The base of the shallow overburden aquifer is set to the deepest elevation of the monitoring wells installed across the Site, resulting in an assumed elevation of 348.9 m AMSL (MW04-18).

Based on the above assumptions, the predicted maximum daily volume of groundwater that could be pumped from the a given length of servicing trench during construction is estimated to be approximately **353,000 L** (Appendix F). Stantec notes that this predicted groundwater volume will likely only be realized during the initial stages of dewatering, with the bulk of this volume representing groundwater that is stored in the overburden deposits. Once this overburden storage is drained and removed from the subsurface, Stantec anticipates that the pumping volumes will lower to reflect a reduced rate of groundwater flowing into the excavation (i.e., normalize to a steady state discharge rate). Stantec notes that these dewatering calculations are preliminary and are subject to change depending on potential changes in the input parameters, such as the proposed the construction approach (e.g., if the length of trench open at one time is different than the 100 m assumed in the current claculations). Additional dewatering calculations can be completed during the detailed design stage of the project to refine dewatering volume predictions and confirm water taking permitting requirements.



Under O. Reg. 64/16 and O. Reg. 63/16, a Ministry of the Environment, Conservation and Parks (MECP) Permit to Take Water (PTTW) is required when construction dewatering rates are anticipated to exceed 400,000 L/day, whereas an Environmental Activity and Sector Registry (EASR) is required when dewatering volumes are expected to range between 50,000 L/day and 400,000 L/day. Consequently, Stantec's opinion is that the Site will require an EASR to complete construction dewatering for the proposed servicing installations.

For long-term groundwater dewatering (via a permanent drainage system), the MECP requires the application for a PTTW if volumes are expected to exceed 50,000 L/day (an EASR does not apply given that long-term permanent dewatering is not associated with construction activities). Since the proposed raising of existing grades at the Site is expected to allow those single residential and townhouse units to be constructed with basements to remain above the high groundwater table (Figures 9 and 10), no permanent drainage system for these homes will be required and, cocnequently, no PTTW will be required to complete this activity.

5.2.2 Dewatering Zone of Influence

One of the issues of concern with the performing of dewatering activities for construction purposes is the potential impact that pumping water from the groundwater system could have on disrupting baseflow contributions to Beaver Creek, Laurel Creek and their associated wetland areas, with these watercourses being located approximately 500 m and 700 m to the south-southwest of the Site, respectively.

The effects of local dewatering in general cannot be mitigated, since dewatering deliberately seeks to create an effect (i.e., temporary lowering of groundwater levels); however, the amount of drawdown expected to occur due to construction activities should remain within a relatively small distance around the excavations. According to the dewatering calculations, the predicted maximum horizontal distance that the pumping zone of influence will extend outward from the active zone of dewatering (i.e., central point of a given servicing trench) is estimated to be no greater than 48 m (Appendix F). Overall, the residual effects of dewatering will be reversible once pumping ceases, groundwater levels will recover and re-equilibrate to the local water table.

5.3 GROUNDWATER FLOW

In areas where site servicing extends below the groundwater table, Stantec recommends that anti-seepage (cut-off) collars be installed to prevent the preferential movement of groundwater along the servicing alignments. The use of anti-seepage collars will likely be required given that sections of the Site subsurface is characterized by deposits where groundwater movement is more restricted (e.g., silt to clay based soils). An assessment for the need, total number and exact placements of anti-seepage collars along the servicing alignments can be explored in more detail during the detailed design phase of the project.

5.4 SPILL CONTAINMENT AND RESPONSE

The Site intersects a WHPA-C, WHPA-D, and SGRA. As such, efforts must be taken during construction to minimize the risk of groundwater quality impacts from potential spills, which given the type of construction is likely to be from the refueling of major construction equipment that cannot readily leave the Site (e.g., earth movers). Potential spills at the Site are expected to be localized and involve a small volume of material, as the Site will not be used for the storage and handling of large volume of chemicals. Based on the above, the following mitigation measures are recommended for potential contaminant spills during construction:

- Trucks or other road vehicles are to be refueled and maintained offsite, where practicable.
- Refueling and lubrication of other construction equipment must not be allowed to occur within 30 m of a drainage system or dewatering excavation.
- Regular inspections of the hydraulic and fuel systems on machinery is to be completed, with identified leaks being repaired immediately upon detection or the equipment being removed from Site.
- Spill kits containing absorbent materials should are to be kept onsite.
- An emergency spill response and reporting plan should be developed and implemented.

6.0 PROPOSED GROUNDWATER MONITORING

The NWSSS (Ecoplans et al., 2013) proposes that *"in addition to typical 'during-construction' monitoring'… pre', 'during' and 'post'- construction…groundwater monitoring should be prepared as part of supporting studies for future development applications. Terms of Reference for monitoring programs should be submitted for approval by agencies having jurisdiction (e.g., GRCA, Region[al Municipality of Waterloo] and City [of Waterloo]) at least two years in advance of a development application being filed on a property."*

The intent of the various stages of proposed monitoring are as follows:

Stage 1. Pre-Construction – Groundwater monitoring within and surrounding the development site to quantitatively identify, and establish a baseline for, hydrogeological site conditions. At minimum two years of monitoring is required. Stantec notes that the monitoring of groundwater levels at BH104 and BH105 has been occurring at the Site since 2007 and at MW7-10 (offsite well located along western limits of the Site) since 2010. In addition, the measuring of groundwater levels in the more recently installed monitoring wells (i.e., MW01-18 to MW07-18) began in February 2018 and is currently ongoing.

Stage 2. During-Construction – Continuation of Stage 1 monitoring, with the addition of monitoring to assess the efficacy of construction mitigation measures. Monitoring should be completed for the duration of construction.

Stage 3. Post-Construction – Monitoring, as required, to assess the efficacy of mitigation measures implemented during construction. At minimum two years of monitoring is required.

Stage 2 and Stage 3 monitoring plans would at a minimum continue the manual monitoring of groundwater levels in all onsite wells: MW01-18 to MW07-18, BH104 and BH105. Stantec also recommends that continuous water level and any water quality data collected at MW7-10 as part of the North Waterloo Phase 1 monitoring program also be reviewed during these stages. As acknowledged by the City, the details of each monitoring phase will be confirmed at each transition stage of the development.

7.0 CONCLUSIONS

The following conclusions are provided based on the completed hydrogeological assessment

1. Stratigraphic conditions beneath the Site consist largely of a 1.4 m to 2.3 m thick layer of silty to sandy fill (up to 5.2 m thick in area of MW07-18) underlain by glaciolacustrine-derived deposits of silt, clayey silt, and silt-textured till, with these deposits being interpreted to represent the Upper Maryhill Till of Aquitard 1 (ATB1). Aquitard 1 ranges from 0.8 m to 4.7 m thick and extends horizontally throughout the subsurface of the Site, except in those areas near MW05-18 and MW07-18 where sand to silty sand deposits (interpreted to represent the silt to sand deposits of Aquifer 1 (AFB1)) come directly into contact with the overlying fill. Sand to silty sand layers ranging from 1.2 m to 1.6 m thick are also found to be occasionally interspersed within Aquitard 1 (ATB1).

2. The high groundwater table tends to be positioned at elevations ranging from 354.13 m AMSL to 354.68 m AMSL in the south half of the Site, equating to depths of less than 0.1 m BGS (MW04-18) to 6.8 m BGS (MW05-18) based on existing grades. The groundwater tends to be shallowest in areas closest to Conservation Drive, with groundwater depths becoming progressively deeper moving to the north across the Site.

3. Groundwater horizontally flows in a south and south-southwest direction across the Site towards Conservation Drive at an average rate of 2.8 m/year.

4. Regional mapping indicates that the Site is characterized as a groundwater recharge area, although the recharge potential of this area is limited by the presence of low permeability clay to silt-textured fill and glaciolacustrine deposits at surface.

5. Groundwater in the shallow groundwater system is calcium-bicarbonate type water. No tested parameters are detected above their applicable health-related ODWS standard.

6. The Site intersects the WHPA-C and WHPA-D for the Waterloo North Production Well W5A, and a SGRA. Preliminary screening of the proposed development through the Region of Waterloo TAPS Source Water Protection Tool will be required as part of the planning approval application process.

7. A water balance analysis for the Site is provided in the Stantec (2019b) Conservation Meadows Subdivision - Phase 2, Functional Servicing and Stormwater Management Report, including the LID stormwater management strategy for the offsetting of predicted annual infiltration losses resulting from the proposed development (i.e., use of infiltration trenches). Since existing grades throughout the Site will be raised to account for the high groundwater table condition, this action will permit the base elevation of infiltration trenches proposed for the development to remain above the groundwater table and, subsequently, allow for these LID structures to function as designed.

8. Based on proposed storm and sanitary invert elevations for the Site, Stantec anticipates that excavation of the trenches required to install this servicing will extend near to, or intercept, the shallow groundwater table, particularly in the southern extents of the Site. The predicted maximum daily volume of groundwater that could be pumped from the a given length of servicing trench at the Site during construction is estimated to be approximately 353,000 L. Consequently, an MECP EASR will be required to complete construction dewatering activities, given that pumped volumes will exceed 50,000 L/day and remain below 400,000 L/day.



9. The effects of local dewatering in general cannot be mitigated, since dewatering deliberately seeks to create an effect (i.e., temporary lowering of groundwater levels); however, the amount of drawdown expected to occur due to construction activities is expected to remain within a relatively small distance around the excavations. According to the dewatering calculations, the predicted maximum horizontal distance that the pumping zone of influence will extend outward from the active zone of dewatering (i.e., central point of a given servicing trench) is estimated to be no greater than 48 m. The pumping zone of influence is not expected to intercept nearby Beaver Creek, Laurel Creek and their associated wetland areas, given that these watercourses are located approximately 500 m and 700 m to the south-southwest of the Site, respectively.

10. A PTTW to complete long-term groundwater dewatering (via a permanent drainage system) is not required for the Site, since the proposed raising of existing grades at the Site is expected to allow those single residential and townhouse units to be constructed with basements to remain above the high groundwater table.

11. In areas where site servicing extends below the groundwater table, Stantec recommends that anti-seepage (cut-off) collars be installed to prevent the preferential movement of groundwater along the servicing alignments. The use of anti-seepage collars will likely be required given that sections of the Site subsurface is characterized by deposits where groundwater movement is more restricted (e.g., silt to clay based soils). An assessment for the need, total number and exact placements of anti-seepage collars along the servicing alignments can be explored in more detail during the detailed design phase of the project.

12. The Site occurs in the North Waterloo Scoped Subwatershed Study Area, and as such a groundwater monitoring program must be established to document pre-, during- and post- construction hydrogeological conditions.

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APPENDIX A:

Figures



Legend

- Property Limit
- Monitoring Well (Stantec, 2018)
- Monitoring Well (Stantec, 2010)
- Monitoring Well (Naylor, 2007)
- Borehole (Naylor, 2002)
- Test Pit (Stantec, 2018)
- Development Plan
- Proposed Sanitary Sewer
- Proposed Stormwater Sewer
- Cross-Section Location
- Proposed Infiltration Gallery
- Road
- Railway
- Watercourse
- Waterbody

0 50 100 metres

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Notes

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Technical Review by BC on 2019-09-25

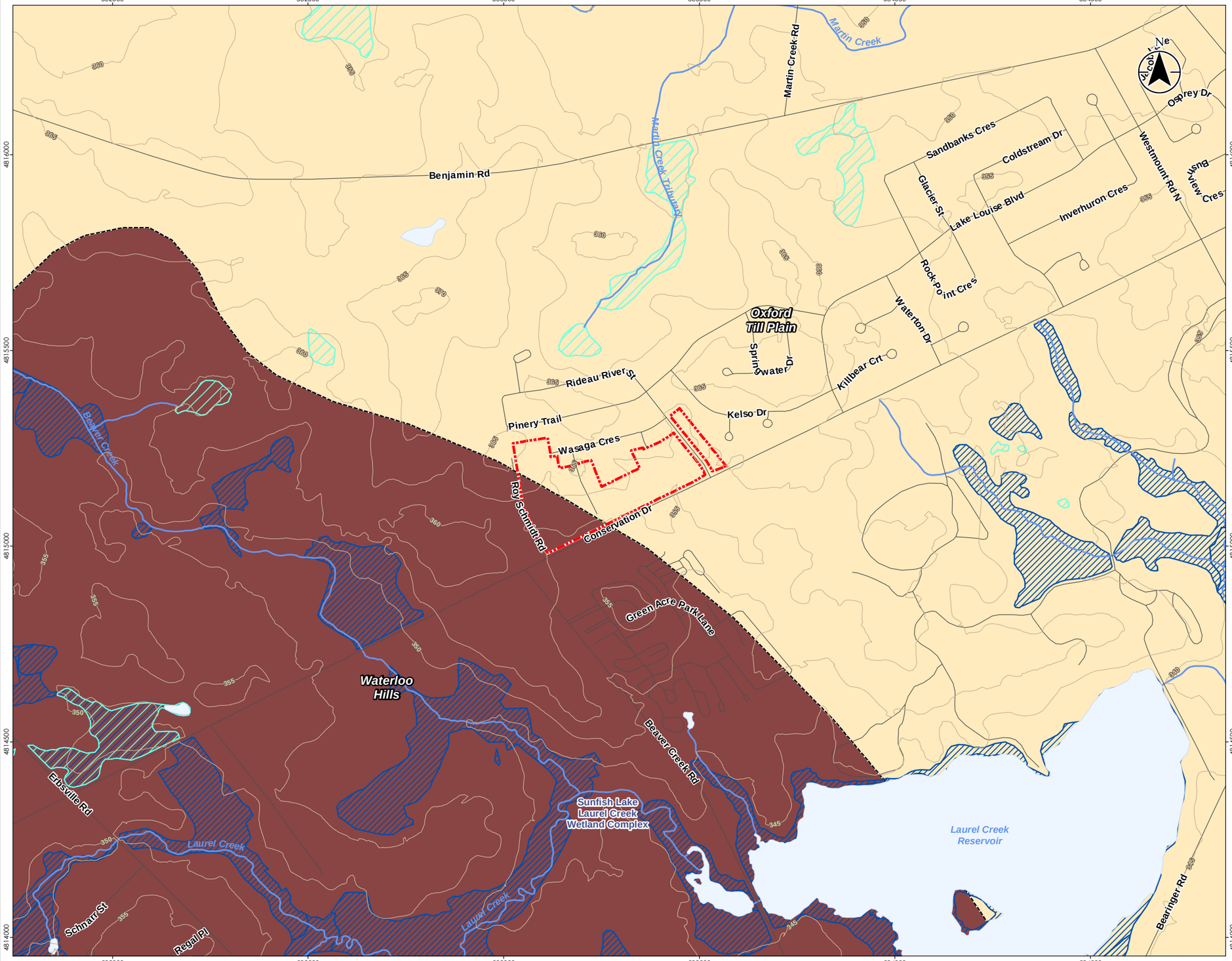
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ACTIVA HOLDINGS INC.
CONSERVATION MEADOWS SUBDIVISON, PHASE 2
HYDROGEOLOGICAL ASSESSMENT

Figure No.
1

Title
Site Plan

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Stantec

Legend

- Property Limit
- Contour (5m Interval)
- Road
- Railway
- Watercourse
- Waterbody
- Wetland - Evaluated (Provincial)
- Wetland - Not evaluated per OWES
- Physiographic Region Boundary

Physiography

- 6: Till Plains (Drumlinized)
- 4: Kame Moraines

0 250 500 metres

1:10,000 (At original document size of 11x17)

Notes

1. Coordinate System: NAD 1983 UTM Zone 17N
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3. Chapman, L.J. and Putnam, D.F. 2007. Physiography of southern Ontario; Ontario Geological Survey, Miscellaneous Release—Data 228.



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Figure No.
2

Title
Physiography

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Stantec

Legend

- Property Limit
- Monitoring Well (Stantec, 2018)
- Monitoring Well (Stantec, 2010)
- Monitoring Well (Naylor, 2007)
- Well Screened in Fill
- Well Screened in Sand
- Well Screened in Silt/Silt Till
- Well Screened in Sand and Silt/Silt Till
- 354.54 High Groundwater Elevation (m AMSL)
- High Groundwater Contour (m AMSL)
- Interpreted Direction of Groundwater Flow
- Topographic Contour (mAMSL)

0 50 100 metres

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Notes

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3. Orthoimagery © First Base Solutions, 2019. Imagery flown in 2018.
4. Highest groundwater levels recorded at MW01-18 to MW07-18 based on measurements obtained between February and April 2018.
5. Highest groundwater levels recorded at BH104 and BH105 based on measurements obtained between January 2011 and April 2018.
6. Highest groundwater level recorded at MW7-10 based on measurements obtained between March 2010 and November 2017.



Project Location
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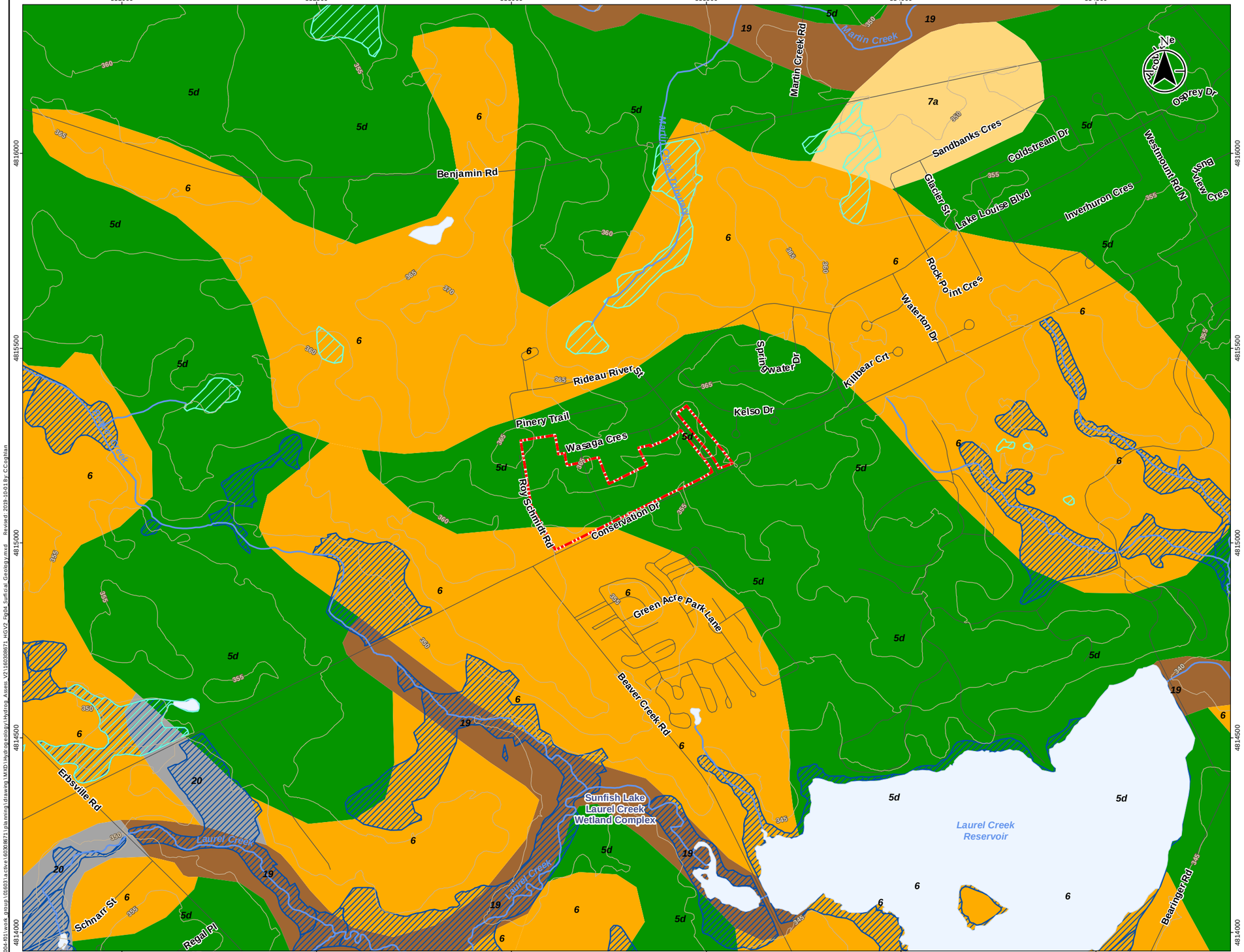
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Figure No.
3

Title
Topography and High Groundwater Condition

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Stantec

Legend

- Property Limit
- Contour (5m Interval)
- Road
- Railway
- Watercourse
- Waterbody
- Wetland - Evaluated (Provincial)
- Wetland - Not evaluated per OWES
- 20: Organic deposits
- 19: Modern alluvial deposits
- 7a: Glaciofluvial deposits (Sandy deposits)
- 6: Ice-contact stratified deposits
- 5d: Glaciolacustrine-derived silty to clayey till

0 250 500 metres

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Notes

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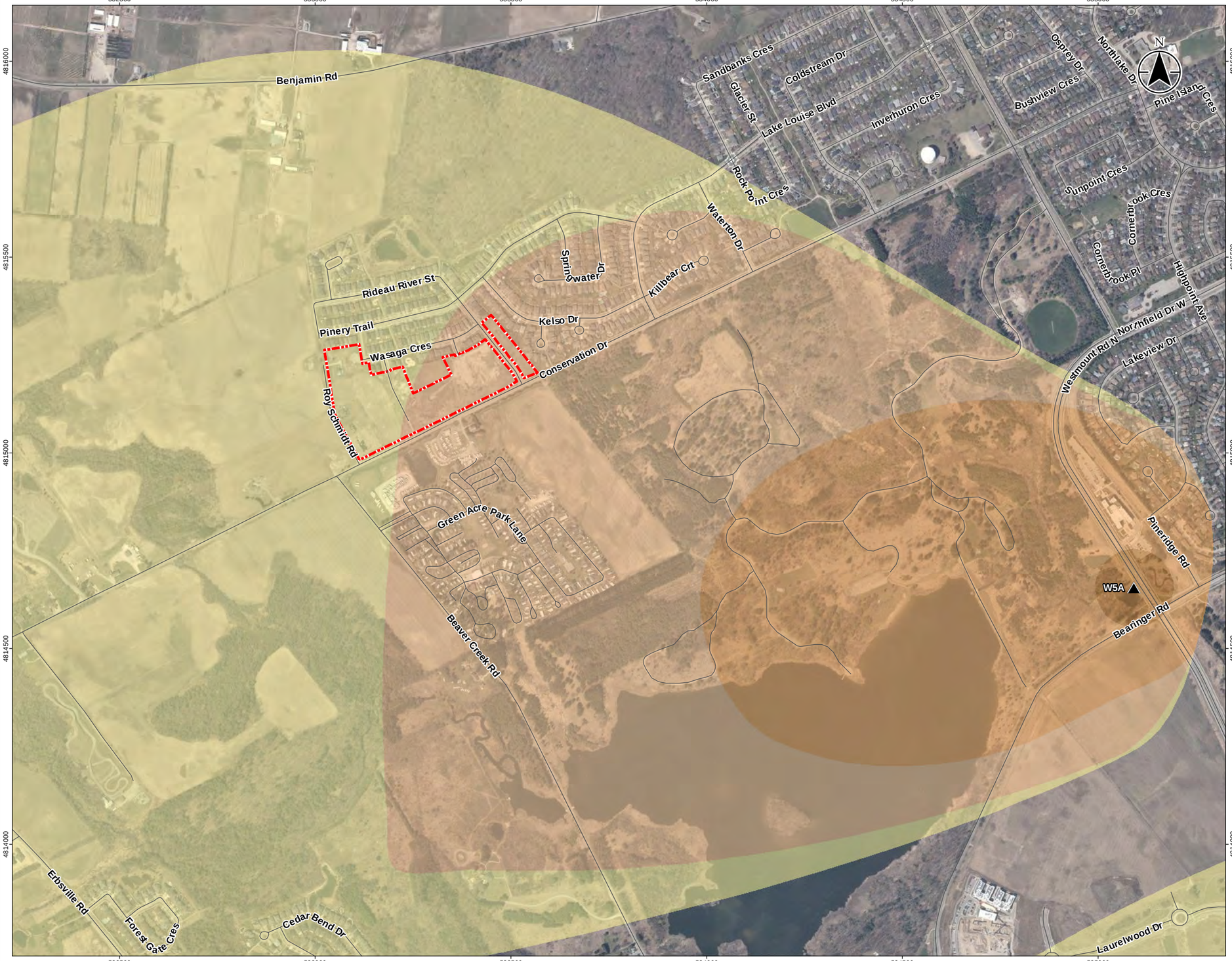
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HYDROGEOLOGICAL ASSESSMENT

Figure No.
4

Title
Surficial Geology

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Stantec

Legend

- Property Limit
- Production Well
- Road
- Railway

Well Head Protection Area

- WHPA A
- WHPA B
- WHPA C
- WHPA D

0 250 500 metres

1:10,000 (At original document size of 11x17)

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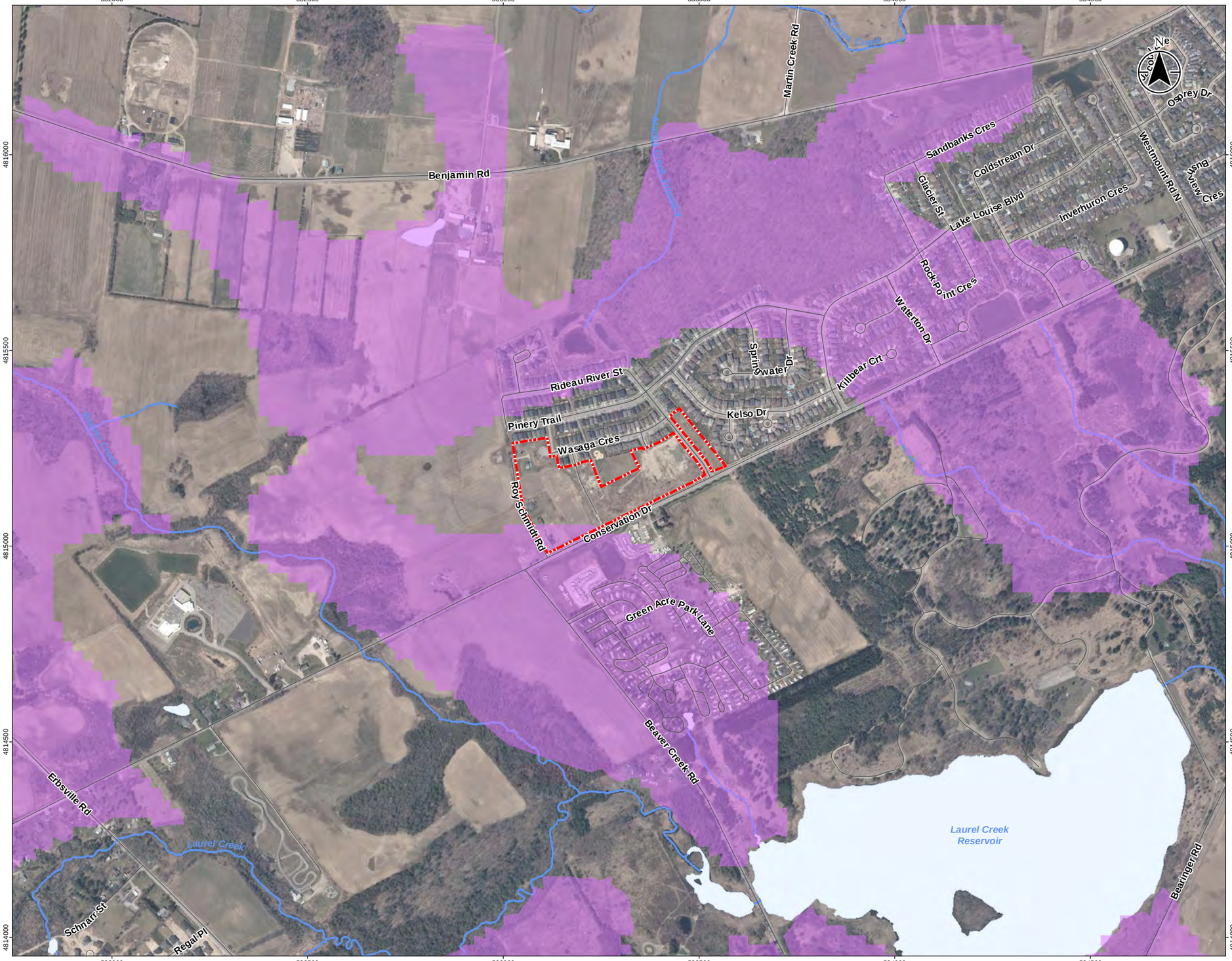
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Figure No.
5

Title
Well Head Protection Areas

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Stantec

Legend

- Property Limit
- Road
- Railway
- Watercourse
- Waterbody
- Significant Groundwater Recharge Area

0 250 500 metres

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Notes

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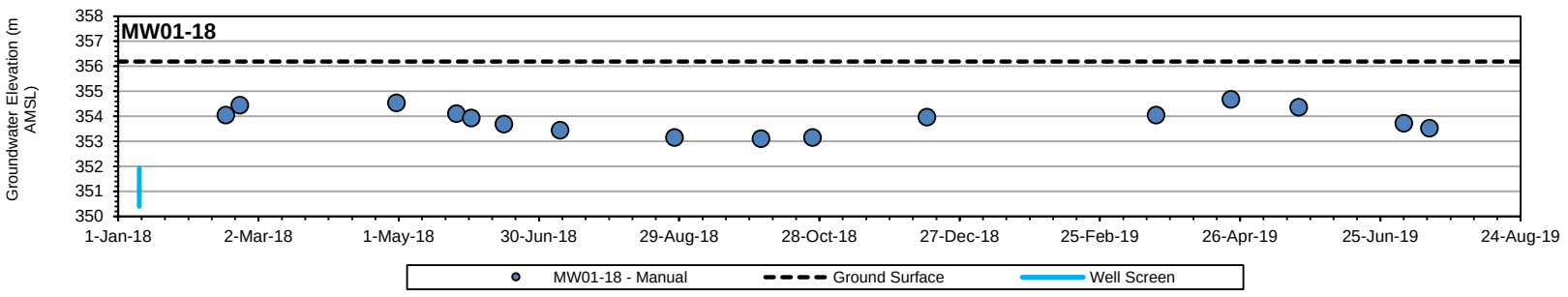
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HYDROGEOLOGICAL ASSESSMENT

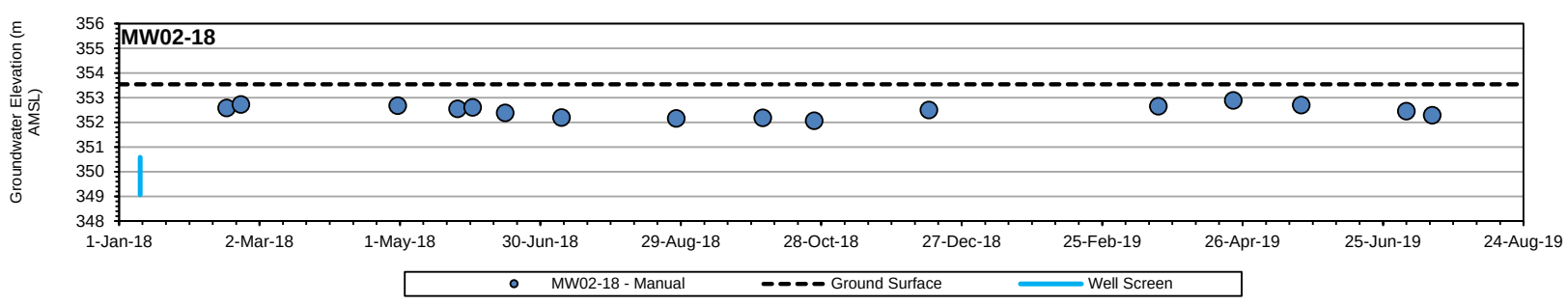
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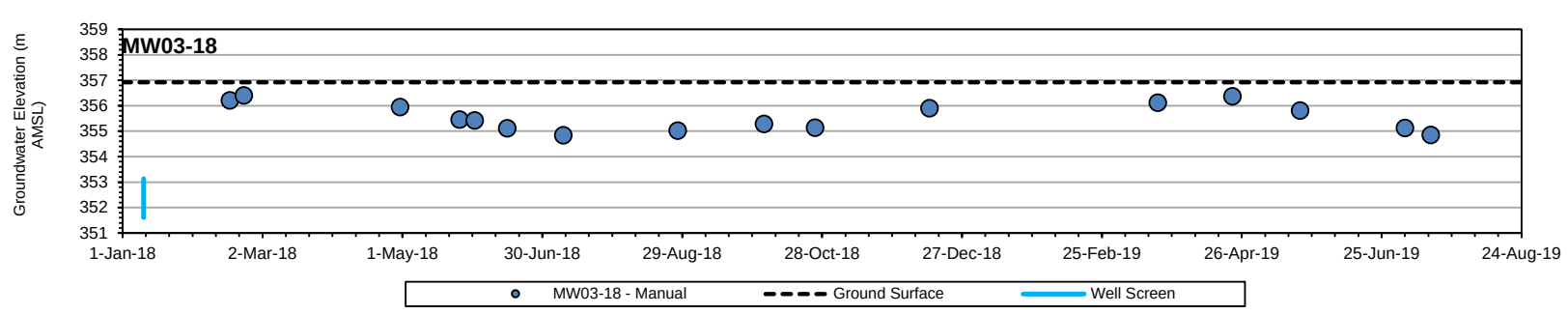
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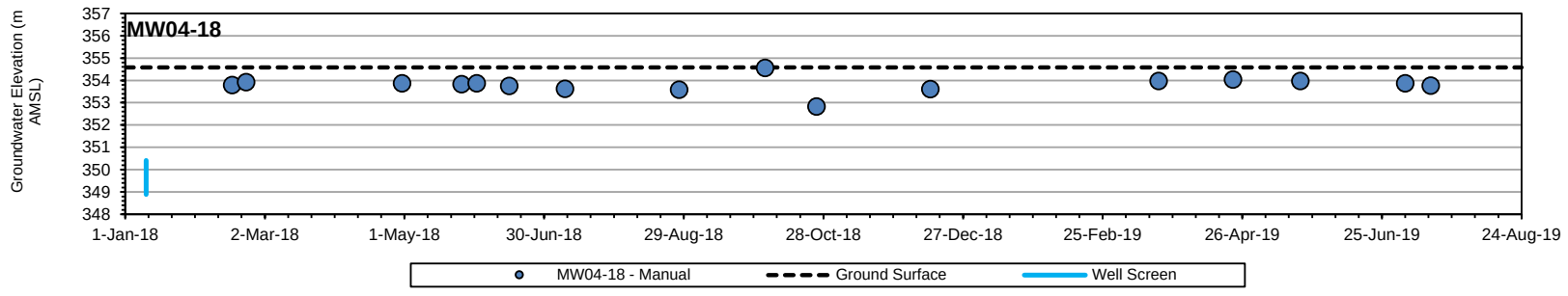
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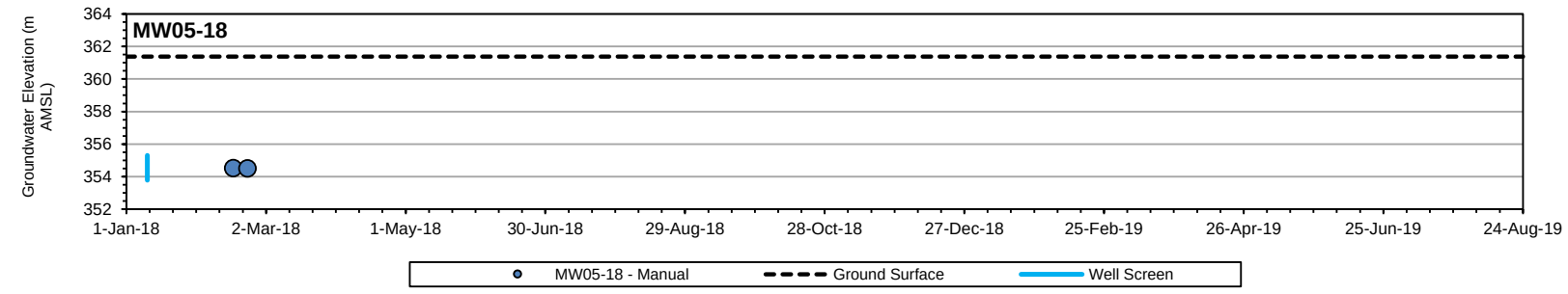
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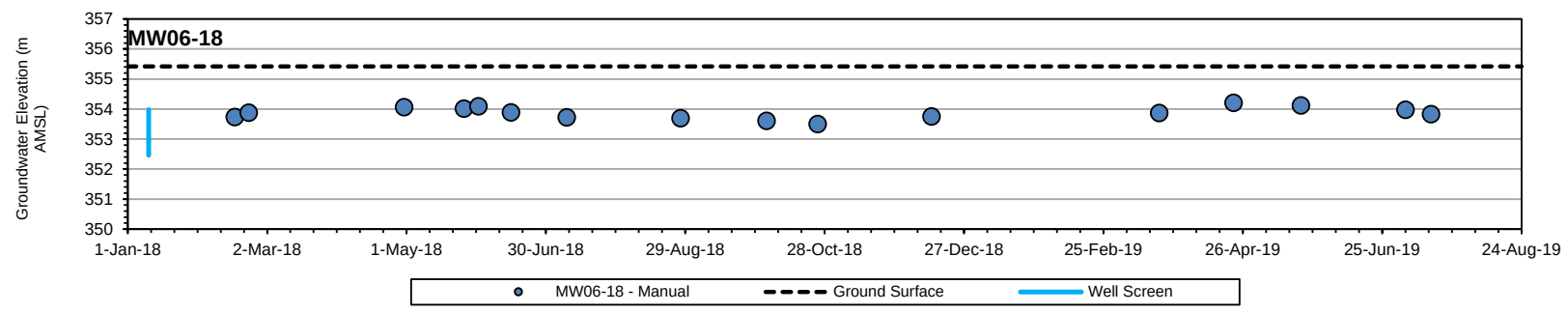


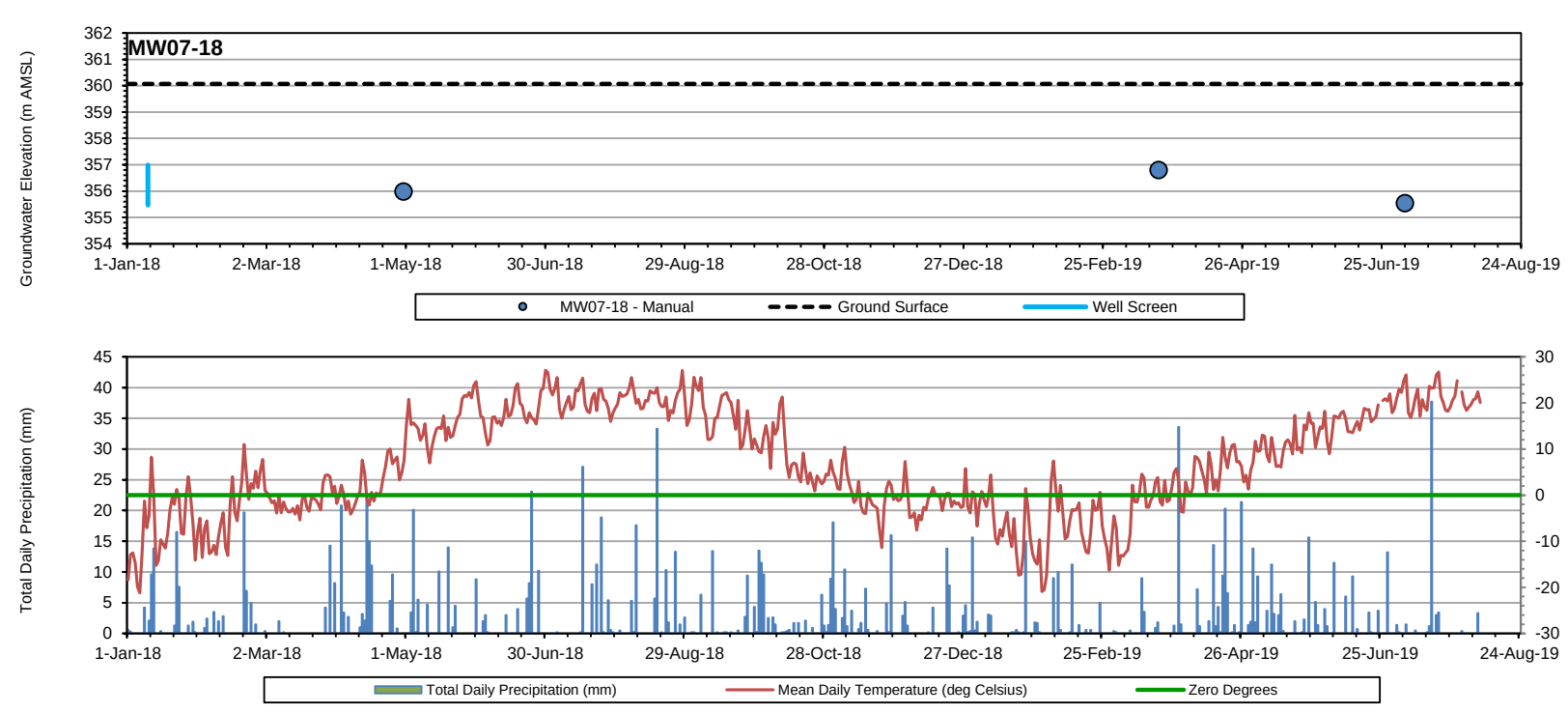












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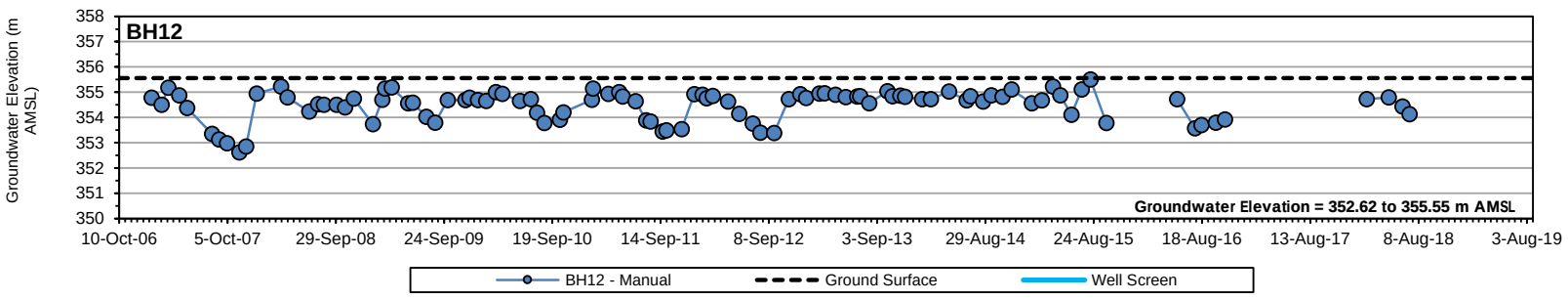
Client/Project

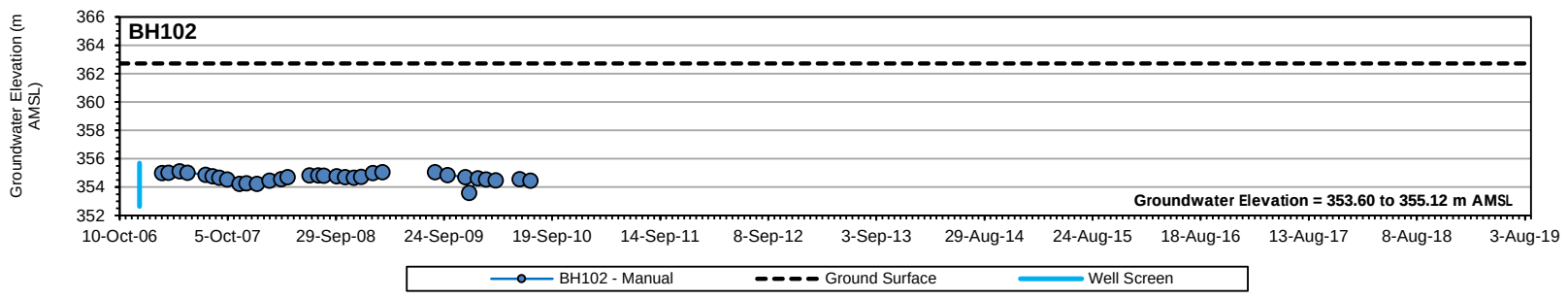
ACTIVA HOLDINGS INC.
CONSERVATION MEADOWS SUBDIVISION, PHASE 2
HYDROGEOLOGICAL ASSESSMENT

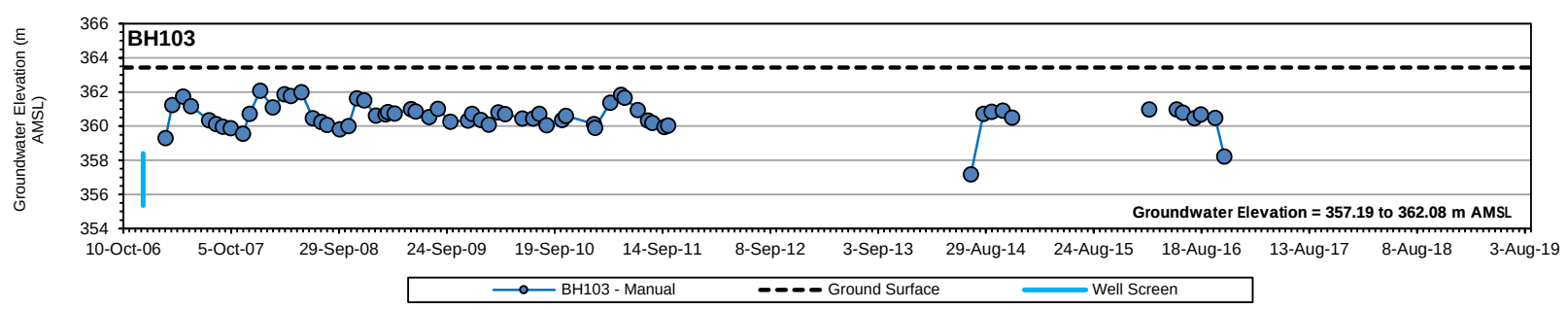
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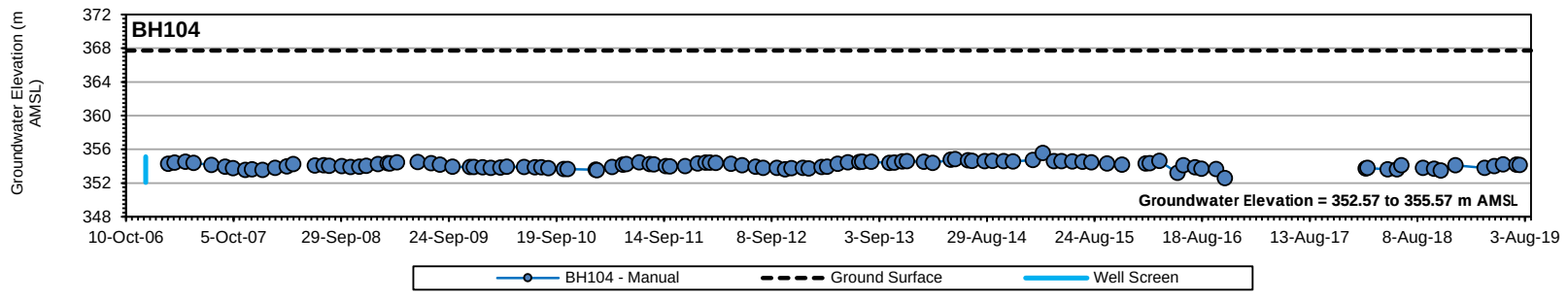
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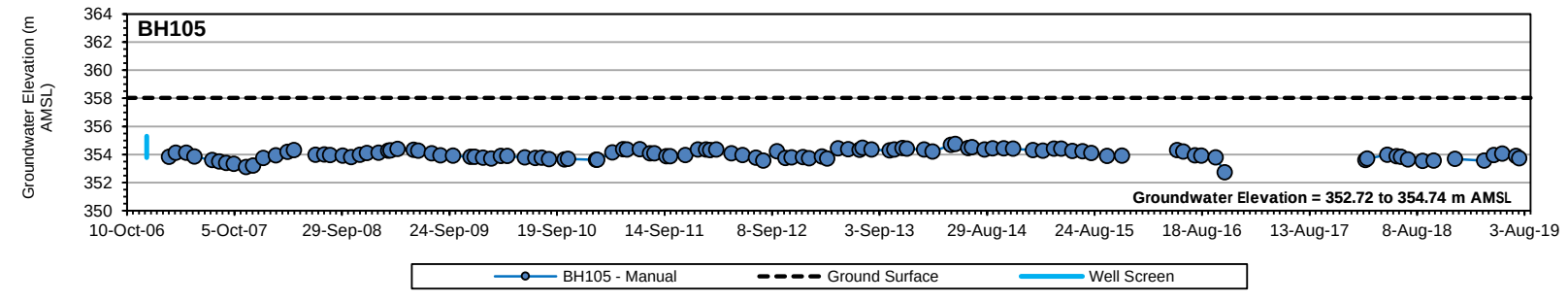
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MW01-18 to MW07-18

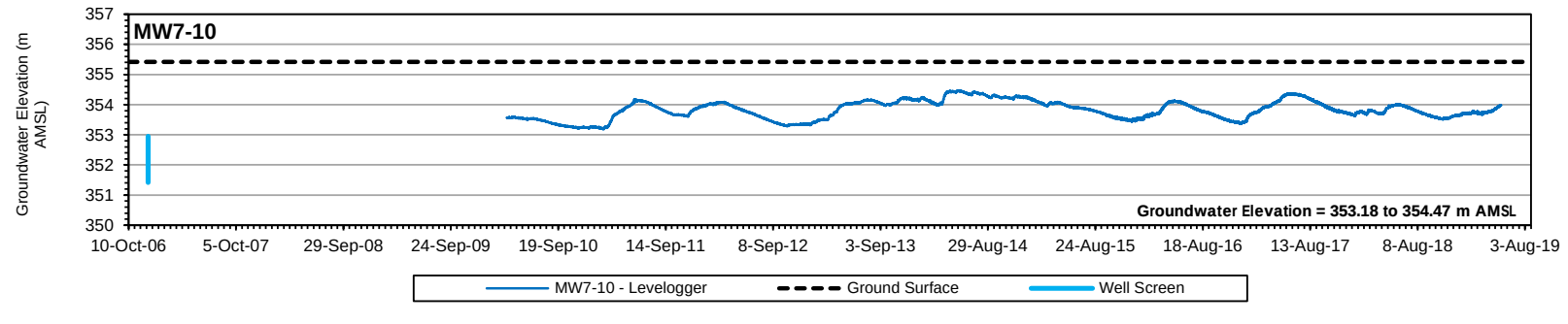


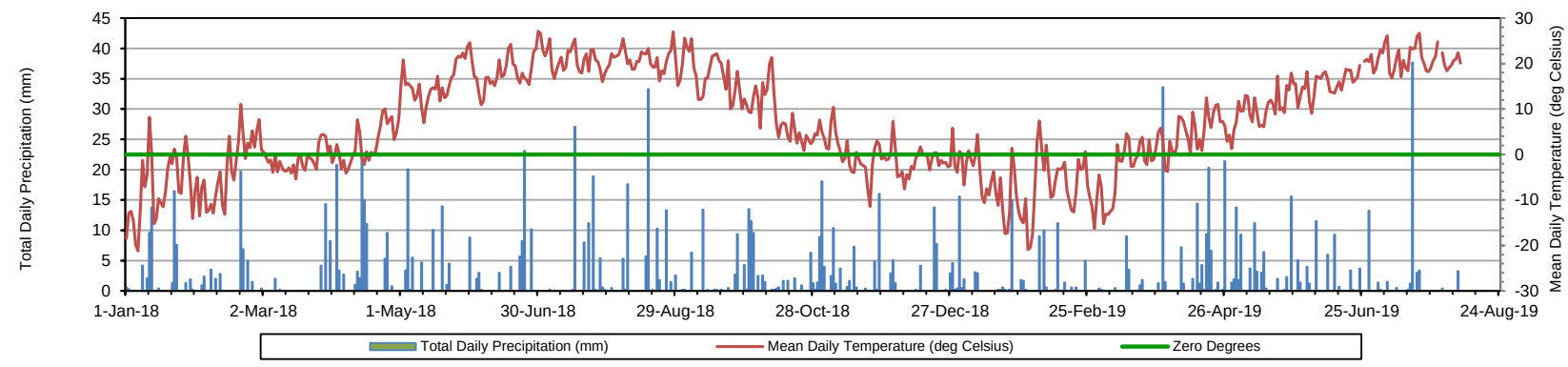












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Client/Project
ACTIVA HOLDINGS INC.
CONSERVATION MEADOWS SUBDIVISION, PHASE 2
HYDROGEOLOGICAL ASSESSMENT

Figure No.
8

Title **HYDROGRAPHS**
BH12, BH102 to BH105 and MW7-10

A
EAST

A'
WEST

MW7-10(OS - 0m)
Roy Schmidt Road
BH 104(OS - 0m)
MW07-18(OS - 0m)
BH 105(OS - 0m)
Rideau River Street

Property Limit
Property Limit

Elevation (mAMSL)

371 370 369 368 367 366 365 364 363 362 361 360 359 358 357 356 355 354 353 352 351 350 349 348 347 346 345

359.32
360.16
361.07
359.17
357.73

TOPSOIL
CLAYEY SILT, trace gravel
SAND (fine to medium grained) trace silt, trace gravel
SILT, trace fine to coarse sand, trace gravel
SAND (fine to medium grained)

356.55
354.60
357.20
356.45
358.50
357.80

FILL (silty topsoil)
SILT TILL (clayey silt, trace sand)
SAND (fine to medium grained), trace silt

357.30
355.80

FILL (silt, sand)
FILL (sand, silt)
FILL (clayey silt)
FILL (silt, sand)
SILT (fine sandy silt)
FILL (silty topsoil)

355.50
354.00

SAND, silty fine to medium sand

AA1



MW7-10 (OS m)

Sand

Well ID (Offset)
Stratigraphy
Water Level (High Groundwater Condition)
Well Screen

Fill / Topsoil
ATB1 Upper Maryhill Till (silty to clayey till) - Aquitard 1
AFB1 Upper Moraine stratified sediments (fine to coarse sand, silt) - Aquifer 1
Proposed Grade
Depth of basement (1.2 m below proposed grade for single residential and townhouse units)

Proposed Infrastructure/Elevation (m AMSL)
Grade
Sanitary
Storm
AA1 Dewatering Assessment Location

10x Vertical Exaggeration
0 25 50 metres

1:1,500 (At original document size of 11x17)

Notes
1. Orthoimagery © First Base Solutions, 2019. Imagery flown in 2018.

Stantec

Project Location
Waterloo, ON

60308671 REVA
Prepared by CMC on 2019-10-01
Technical Review by BC on 2019-09-25

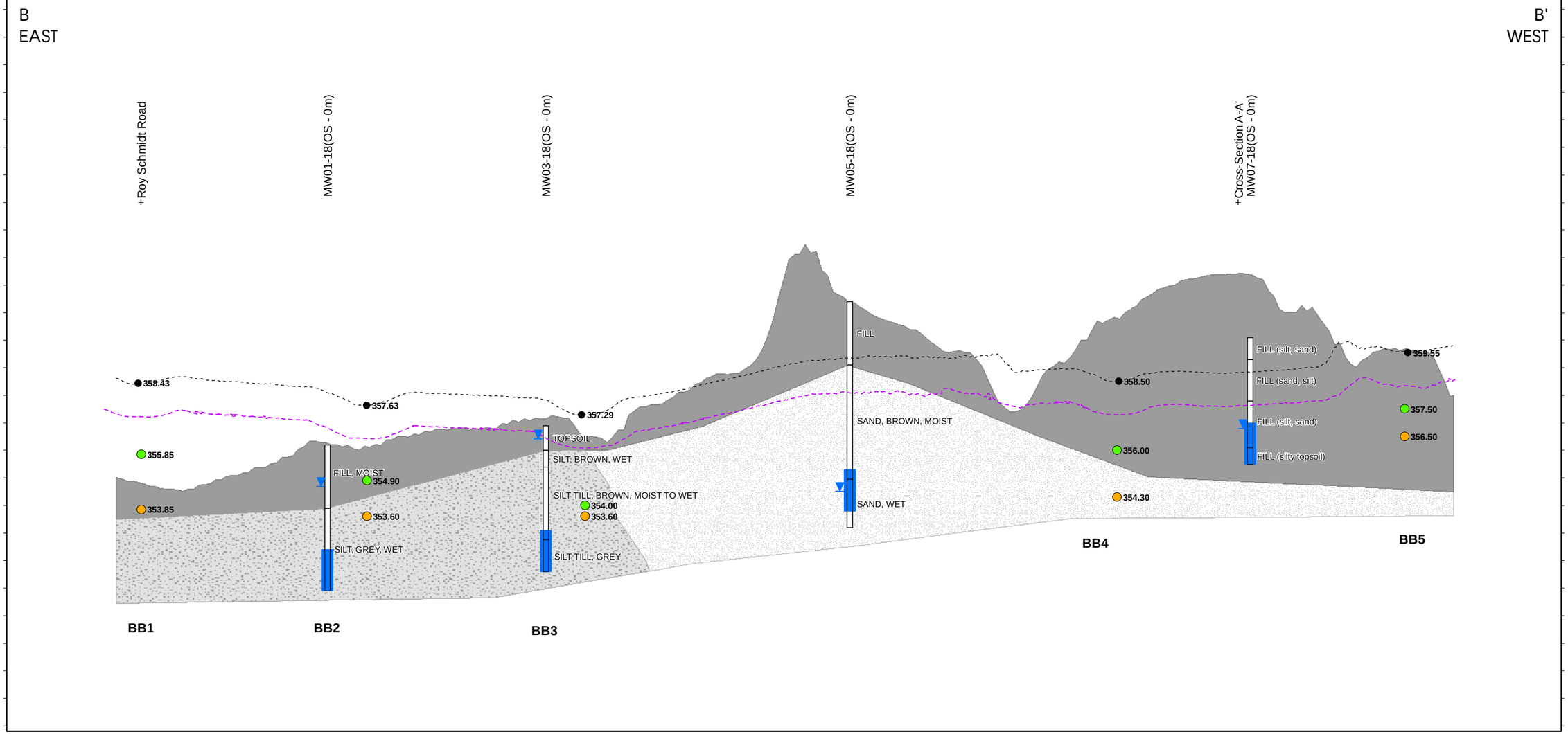
Client/Project
ACTIVA HOLDINGS INC.
CONSERVATION MEADOWS SUBDIVISON, PHASE 2
HYDROGEOLOGICAL ASSESSMENT

Figure No.
9

Title
Cross-Section A-A'

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Notes
1. Orthoimagery © First Base Solutions, 2019. Imagery flown in 2018.

MW7-10 (OS m)
Sand
Well ID (Offset)
Stratigraphy
Water Level (High Groundwater Condition)
Well Screen

Fill / Topsoil
ATB1 Upper Maryhill Till (silty to clayey till) - Aquitard 1
AFB1 Upper Moraine stratified sediments (fine to coarse sand, silt) - Aquifer 1
Proposed Grade
Depth of basement (1.2 m below proposed grade for single residential and townhouse units)

Proposed Infrastructure/Elevation (m AMSL)
Grade
Sanitary
Storm
BB1 Dewatering Assessment Location

10x Vertical Exaggeration
0 25 50 metres
1:1,500 (At original document size of 11x17)

Stantec

Project Location
Waterloo, ON

60308671 REVA
Prepared by CMC on 2019-10-01
Technical Review by BC on 2019-09-25

Client/Project
ACTIVA HOLDINGS INC.
CONSERVATION MEADOWS SUBDIVISON, PHASE 2
HYDROGEOLOGICAL ASSESSMENT

Figure No.
10

Title
Cross-Section B-B'

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C
EAST

C'
WEST

Elevation (mAMSL)

+Roy Schmidt Road
MW02-18(OS - 0m)
MW04-18(OS - 0m)
TP03-18(OS - 0m)
MW06-18(OS - 0m)
BH105(OS - 0m)
+Cross-Section A-A'
+Rideau River Street

354.96
356.50
357.86
355.50
354.00
352.65
351.80
351.10

TOPSOIL
SILTY CLAY, brown, moist to wet
SILT TILL, light grey, wet
SILT, grey, wet
TOPSOIL
SILT, brown, wet
SAND, brown, wet
SILT TILL, grey, wet
TOPSOIL
SILT
FILL (sandy topsoil)
SILT, grey, wet
SILTY SAND, brown, wet
FILL (clayey silt)
SILT (fine sandy silt)
SAND (silty fine to medium sand)

CC1
CC2
CC3



MW7-10 (OS m)
Sand
Well ID (Offset)
Stratigraphy
Water Level (High Groundwater Condition)
Well Screen

Fill / Topsoil
ATB1 Upper Maryhill Till (silty to clayey till) - Aquitard 1
AFB1 Upper Moraine stratified sediments (fine to coarse sand, silt) - Aquifer 1
----- Proposed Grade
Proposed Infrastructure/Elevation (m AMSL)
Grade
Sanitary
Storm
CC1 Dewatering Assessment Location

10x Vertical Exaggeration
0 25 50 metres
1:1,500 (At original document size of 11x17)

Notes
1. Orthoimagery © First Base Solutions, 2019. Imagery flown in 2018.

* Townhouses along Conservation Drive are proposed as slab on grade

Stantec

Project Location
Waterloo, ON

60308671 REVA
Prepared by CMC on 2019-10-01
Technical Review by BC on 2019-09-25

Client/Project
ACTIVA HOLDINGS INC.
CONSERVATION MEADOWS SUBDIVISON, PHASE 2
HYDROGEOLOGICAL ASSESSMENT

Figure No.
11

Title
Cross-Section C-C'

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APPENDIX B:

Tables

TABLE 1
WELL CONSTRUCTION DETAILS
CONSERVATION MEADOWS SUBDIVISION PHASE II
ACTIVA HOLDINGS INC.

Well ID	Installed By	UTM Coordinates (NAD 83 Zn 17 N)		Elevations		Well Stick-up (m)	Borehole Depth		Screened Interval				Screened Material Description	Hydraulic Conductivity (m/s)
		Northing	Easting	Top of Casing (m AMSL)	Ground Surface (m AMSL)		(m BGS)	(m AMSL)	Top Elevation (m BGS)	Top Elevation (m AMSL)	Bottom Elevation (m BGS)	Bottom Elevation (m AMSL)		
BH12	Naylor	4815063	533159	356.47	355.56	0.91	--	--	--	--	--	--	--	--
BH102	Naylor (2007)	4815380	533145	363.42	362.72	0.70	10.36	352.36	7.03	355.69	10.08	352.64	SAND	--
BH103	Naylor (2007)	4815360	533341	364.10	363.43	0.67	8.08	355.35	5.03	358.40	8.08	355.35	SILT TILL	--
BH104	Naylor (2007)	4815224	533266	363.39	362.72	0.67	10.67	352.05	7.60	355.12	10.65	352.07	SAND	--
BH105	Naylor (2007)	4815206	533497	358.88	358.03	0.85	6.55	351.48	3.05	354.98	6.10	351.93	SAND	--
MW7-10	Stantec (2010)	4815108	533031	359.67	358.74	0.93	8.23	350.51	5.79	352.95	7.32	351.42	SAND	8.7E-05
MW01-18	Stantec (2018)	4815068	533136	356.97	356.19	0.78	5.79	350.40	4.27	351.92	5.79	350.40	SILT	6.3E-07
MW02-18	Stantec (2018)	4815023	533166	354.24	353.54	0.70	4.48	349.06	2.96	350.58	4.48	349.06	SILT, some clay	5.9E-07
MW03-18	Stantec (2018)	4815103	533207	357.76	356.92	0.84	5.31	351.61	3.79	353.13	5.31	351.61	SILT TILL	6.0E-08
MW04-18	Stantec (2018)	4815054	533235	355.47	354.58	0.89	5.69	348.89	4.17	350.41	5.69	348.89	SAND (53%) / SILT TILL (47%)	2.8E-05
MW05-18	Stantec (2018)	4815150	533307	362.11	361.38	0.73	7.60	353.78	6.08	355.30	7.60	353.78	Fine SAND	-
MW06-18	Stantec (2018)	4815139	533407	356.26	355.42	0.84	2.96	352.46	1.44	353.98	2.96	352.46	SILT (53%) / Silty SAND (47%)	1.5E-05
MW07-18	Stantec (2018)	4815212	533438	360.89	360.07	0.82	4.60	355.47	3.08	356.99	4.60	355.47	FILL (Silt, Sand, Silty Topsoil)	-
													Geomean (SAND) =	**3.3E-05**
													Geomean (SILT) =	**2.8E-07**
													Geomean (ALL SOILS) =	**3.1E-06**

Notes:
m AMSL = meters above mean sea level
m BGS = meters below ground surface
m BTOC = meters below top of well casing
- = data not available

TABLE 2
GROUNDWATER LEVELS
CONSERVATION MEADOWS SUBDIVISION PHASE II
ACTIVA HOLDINGS INC.

Well ID	Date	Time	Well Depth		Top of Casing Elevation	Ground Surface Elevation	Pipe Stick-up	Groundwater Level		
			(m BGS)	(m AMSL)	(m AMSL)	(m AMSL)	(m)	(m BGS) [1]	(m BTOC)	(m AMSL)
MW01-18	16-Feb-18	-	5.79	350.40	356.97	356.19	0.78	2.14	2.92	354.05
	22-Feb-18	-						1.74	2.52	354.45
	30-Apr-18	-						1.65	2.43	354.54
	25-May-18	2:47 PM						2.08	2.86	354.11
	1-Jun-18	-						2.26	3.04	353.93
	15-Jun-18	-						2.50	3.28	353.69
	9-Jul-18	-						2.75	3.53	353.44
	27-Aug-18	-						3.04	3.82	353.15
	3-Oct-18	-						3.08	3.86	353.11
	25-Oct-18	-						3.03	3.81	353.16
	13-Dec-18	-						2.22	3.00	353.97
	21-Mar-19	-						2.14	2.92	354.05
	22-Apr-19	-						1.51	2.29	354.68
	21-May-19	-						1.82	2.60	354.37
	5-Jul-19	-						2.47	3.25	353.72
	16-Jul-19	-						2.66	3.44	353.53
MW02-18	16-Feb-18	-	4.48	349.06	354.24	353.54	0.70	0.96	1.66	352.58
	22-Feb-18	-						0.81	1.51	352.73
	30-Apr-18	-						0.86	1.56	352.68
	25-May-18	3:17 PM						0.99	1.69	352.55
	1-Jun-18	-						0.93	1.63	352.61
	15-Jun-18	-						1.15	1.85	352.39
	9-Jul-18	-						1.34	2.04	352.20
	27-Aug-18	-						1.38	2.08	352.16
	3-Oct-18	-						1.35	2.05	352.19
	25-Oct-18	-						1.47	2.17	352.07
	13-Dec-18	-						1.04	1.74	352.50
	21-Mar-19	-						0.88	1.58	352.66
	22-Apr-19	-						0.65	1.35	352.89
	21-May-19	-						0.84	1.54	352.70
	5-Jul-19	-						1.09	1.79	352.46
	16-Jul-19	-						1.25	1.95	352.29
MW03-18	16-Feb-18	-	5.31	351.61	357.76	356.92	0.84	0.71	1.55	356.21
	22-Feb-18	-						0.51	1.35	356.41
	30-Apr-18	-						0.97	1.81	355.95
	25-May-18	11:33 AM						1.46	2.30	355.46
	1-Jun-18	-						1.49	2.33	355.43
	15-Jun-18	-						1.80	2.64	355.12
	9-Jul-18	-						2.08	2.92	354.84
	27-Aug-18	-						1.89	2.73	355.03
	3-Oct-18	-						1.63	2.47	355.29
	25-Oct-18	-						1.78	2.62	355.14
	13-Dec-18	-						1.01	1.85	355.91
	21-Mar-19	-						0.80	1.64	356.12
	22-Apr-19	-						0.55	1.39	356.37
	21-May-19	-						1.10	1.94	355.82
	5-Jul-19	-						1.79	2.63	355.13
	16-Jul-19	-						2.06	2.90	354.86
MW04-18	16-Feb-18	-	5.69	348.89	355.47	354.58	0.89	0.80	1.69	353.78
	22-Feb-18	-						0.66	1.55	353.92
	30-Apr-18	-						0.71	1.60	353.87
	25-May-18	12:16 PM						0.75	1.64	353.83
	1-Jun-18	-						0.71	1.60	353.87
	15-Jun-18	-						0.83	1.72	353.75
	9-Jul-18	-						0.96	1.85	353.62
	27-Aug-18	-						1.00	1.89	353.58
	3-Oct-18	-						0.03	0.92	354.55
	25-Oct-18	-						1.76	2.65	352.82
	13-Dec-18	-						0.97	1.86	353.61
	21-Mar-19	-						0.61	1.50	353.97
	22-Apr-19	-						0.55	1.44	354.03
	21-May-19	-						0.61	1.50	353.97
	5-Jul-19	-						0.72	1.61	353.86
	16-Jul-19	-						0.82	1.71	353.76

TABLE 2
GROUNDWATER LEVELS
CONSERVATION MEADOWS SUBDIVISION PHASE II
ACTIVA HOLDINGS INC.

Well ID	Date	Time	Well Depth		Top of Casing Elevation	Ground Surface Elevation	Pipe Stick-up	Groundwater Level		
			(m BGS)	(m AMSL)	(m AMSL)	(m AMSL)	(m)	(m BGS) [1]	(m BTOC)	(m AMSL)
MW05-18	16-Feb-18	-	7.60	353.78	362.11	361.38	0.73	6.86	7.60	354.52
	22-Feb-18	-						6.89	7.62	354.49
	30-Apr-18	-						-	-	-
	25-May-18	9:34 AM						-	DRY	-
	1-Jun-18	-						-	-	-
	15-Jun-18	-						-	DRY	-
	9-Jul-18	-						-	DRY	-
	27-Aug-18	-						-	DRY	-
	3-Oct-18	-						-	DRY	-
	25-Oct-18	-						-	DRY	-
	13-Dec-18	-						-	DRY	-
	21-Mar-19	-						-	-	-
	22-Apr-19	-						-	-	-
	21-May-19	-						-	-	-
	5-Jul-19	-						-	-	-
	16-Jul-19	-						-	-	-
MW06-18	16-Feb-18		2.96	352.46	356.26	355.42	0.84	1.69	2.53	353.73
	22-Feb-18							1.55	2.39	353.87
	30-Apr-18							1.36	2.20	354.06
	25-May-18	4:53 PM						1.41	2.25	354.01
	1-Jun-18	-						1.33	2.17	354.09
	15-Jun-18	-						1.54	2.38	353.88
	9-Jul-18	-						1.70	2.54	353.72
	27-Aug-18	-						1.73	2.57	353.69
	3-Oct-18	-						1.82	2.66	353.60
	25-Oct-18	-						1.92	2.76	353.50
	13-Dec-18	-						1.67	2.51	353.75
	21-Mar-19	-						1.56	2.40	353.86
	22-Apr-19	-						1.22	2.06	354.20
	21-May-19	-						1.30	2.14	354.12
	5-Jul-19	-						1.45	2.29	353.97
	16-Jul-19	-						1.59	2.43	353.83
MW07-18	16-Feb-18		4.60	355.47	360.89	360.07	0.82	-	DRY	-
	22-Feb-18							-	DRY	-
	30-Apr-18							4.08	4.90	355.99
	25-May-18	9:42 AM						-	DRY	-
	1-Jun-18	-						-	DRY	-
	15-Jun-18	-						-	DRY	-
	9-Jul-18	-						-	DRY	-
	27-Aug-18	-						-	DRY	-
	3-Oct-18	-						-	DRY	-
	25-Oct-18	-						-	DRY	-
	13-Dec-18	-						-	DRY	-
	21-Mar-19	-						3.27	4.09	356.80
	22-Apr-19	-						-	DRY	-
	21-May-19	-						-	DRY	-
	5-Jul-19	-						4.53	5.35	355.54
	16-Jul-19	-						-	DRY	-
BH104	16-Feb-18		10.67	352.05	363.39	362.72	0.67	8.79	9.46	353.93
	22-Feb-18							8.74	9.41	353.98
	30-Apr-18							8.93	9.60	353.79
	25-May-18							-	-	-
	1-Jun-18							8.92	9.59	353.80
	15-Jun-18							8.47	9.14	354.25
	9-Jul-18							-	DRY	-
	27-Aug-18							8.76	9.43	353.96
	3-Oct-18							8.94	9.61	353.78
	25-Oct-18							-	DRY	-
	13-Dec-18							8.43	9.10	354.29
	21-Mar-19							8.75	9.42	353.97
	22-Apr-19							8.55	9.22	354.17
	21-May-19							8.33	9.00	354.39
	5-Jul-19							8.26	8.93	354.46
	16-Jul-19							8.45	9.12	354.27

TABLE 2
GROUNDWATER LEVELS
CONSERVATION MEADOWS SUBDIVISION PHASE II
ACTIVA HOLDINGS INC.

Well ID	Date	Time	Well Depth		Top of Casing Elevation	Ground Surface Elevation	Pipe Stick-up	Groundwater Level		
			(m BGS)	(m AMSL)	(m AMSL)	(m AMSL)	(m)	(m BGS) [1]	(m BTOC)	(m AMSL)
BH105	16-Feb-18		6.55	351.48	358.88	358.03	0.85	4.39	5.24	353.64
	22-Feb-18							4.27	5.12	353.76
	30-Apr-18							3.95	4.80	354.08
	25-May-18	4:53 PM						-	-	-
	1-Jun-18	-						4.04	4.89	353.99
	15-Jun-18	-						4.12	4.97	353.91
	9-Jul-18	-						4.30	5.15	353.73
	27-Aug-18	-						4.37	5.22	353.66
	3-Oct-18	-						4.45	5.30	353.58
	25-Oct-18	-						-	DRY	-
	13-Dec-18	-						4.27	5.12	353.76
	21-Mar-19	-						4.35	5.20	353.68
	22-Apr-19	-						3.95	4.80	354.08
	21-May-19	-						3.85	4.70	354.18
	5-Jul-19	-						4.02	4.87	354.01
	16-Jul-19	-						4.14	4.99	353.89

Notes:

m AMSL = meters above mean sea level
m BGS = meters below ground surface
m BTOC = meters below top of well casing
- = data not available

TABLE 3
GROUNDWATER ANALYTICAL RESULTS - MW7/10
As Summarized from the Waterloo North Hydrogeological Assessment (Stantec, 2016)

Sample Location			MW7-10						
Sample Date			17-May-10	17-May-10	17-May-10	26-Oct-10	26-Oct-10	22-Aug-14	28-Sep-15
Sample ID			WG-160340875-20100517-AV02	WG-160340875-20100517-AV03	WG-160340875-20100517-AV03LR	WG-160340875-20101026-JK11	WG-160340875-20101026-JK11LR	WG-160310875-20140822-AV12	WG-160310875-20150928-AV02
Sampling Company			STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC
Laboratory			MAXX	MAXX	MAXX	MAXX	MAXX	MAXX	MAXX
Laboratory Work Order			B062483	B062483	B062483	B0F2316	B0F2316	B4F3646	B5J8856
Laboratory Sample ID			FX4442	FX4443	FX4443	HQ0827	HQ0827	XG4195	BBU087
Sample Type	Units	ODWS		Field Duplicate	Lab Replicate		Lab Replicate		
Field Parameters									
Dissolved oxygen, Field	mg/L	n/v	6.9	-	-	1.2	-	-	-
Specific Conductivity	mS/cm	n/v	-	-	-	-	-	-	0.372
Oxidation Reduction Potential, field	mV	n/v	-	-	-	-	-	-	-
pH, Field	S.U.	6.5-8.5[D]	7.6	-	-	-	-	7.38	7.44
Specific Conductance, Field	µS/cm	n/v	645	-	-	-	-	544	-
Temperature, Field	deg C	15[C]	9.4	-	-	-	-	9.1	10.1
General Chemistry									
Alkalinity, Bicarbonate (as CaCO3)	mg/L	n/v	267	283	-	313	-	250	280
Alkalinity, Carbonate (as CaCO3)	mg/L	n/v	2	2	-	3	-	2.1	1.9
Alkalinity, Total (as CaCO3)	mg/L	30-500[D]	269	286	-	316	-	260	280
Ammonia (as N)	mg/L	n/v	0.06	0.06	-	0.09	-	<0.050	<0.050
Anion Sum	meq/L	n/v	6.23	6.54	-	7.18	-	5.55	6.24
Cation Sum	meq/L	n/v	7.31	6.97	-	7.23	-	5.79	6.24
Chloride	mg/L	250[C]	10	10	-	10	9	6	8.7
Dissolved Organic Carbon (DOC)	mg/L	5[C]	0.9	0.8	-	1.2	-	0.48	0.69
Electrical Conductivity, Lab	µmhos/cm	n/v	571	599	-	654	-	510	570
Hardness (as CaCO3)	mg/L	80-100[D]	**350[D]**	**340[D]**	-	**350[D]**	-	**280[D]**	**300[D]**
Ion Balance	%	n/v	8.00	3.24	-	0.350	-	2.05	0.0100
Langelier Index (at 20 C)	none	n/v	0.936	0.932	-	1.02	-	0.846	0.808
Langelier Index (at 4 C)	none	n/v	0.687	0.684	-	0.769	-	0.597	0.559
Nitrate (as N)	mg/L	10.0_d[A]	2.6	2.6	-	3.0	-	1.87	2.56
Nitrate + Nitrite (as N)	mg/L	10.0_d[A]	2.6	2.6	-	3.0	-	1.87	2.56
Nitrite (as N)	mg/L	1.0_d[A]	<0.01	<0.01	-	<0.01	-	<0.010	<0.010
Orthophosphate(as P)	mg/L	n/v	<0.01	<0.01	-	<0.01	<0.01	<0.010	<0.010
pH	S.U.	6.5-8.5[D]	7.9	7.9	-	7.96	-	7.95	7.85
Saturation pH (at 20 C)	none	n/v	7.01	7.00	-	6.94	-	7.11	7.04
Saturation pH (at 4 C)	none	n/v	7.25	7.25	-	7.19	-	7.36	7.29
Sulfate	mg/L	500_h[C]	18	18	-	18	18	7	9.9
Total Dissolved Solids (Calculated)	mg/L	500[C]	344	347	-	373	-	290	320
Metals									
Aluminum	mg/L	0.1[D]	<0.005	<0.005	<0.005	<0.005	-	<0.0050	<0.0050
Antimony	mg/L	0.006[B]	<0.0005	<0.0005	<0.0005	<0.0005	-	<0.00050	<0.00050
Arsenic	mg/L	0.025[B]	<0.001	<0.001	<0.001	<0.001	-	<0.0010	<0.0010
Barium	mg/L	1[A]	0.025	0.023	0.024	0.021	-	0.015	0.015
Beryllium	mg/L	n/v	<0.0005	<0.0005	<0.0005	<0.0005	-	<0.00050	<0.00050
Boron	mg/L	5[B]	<0.01	0.01	0.01	<0.01	-	<0.010	<0.010
Cadmium	mg/L	0.005[A]	<0.0001	<0.0001	<0.0001	0.0001	-	<0.00010	<0.00010
Calcium	mg/L	n/v	99	95	95	100	-	80	86
Chromium	mg/L	0.05[A]	<0.005	<0.005	<0.005	<0.005	-	<0.0050	<0.0050
Cobalt	mg/L	n/v	<0.0005	<0.0005	<0.0005	<0.0005	-	<0.00050	<0.00050
Copper	mg/L	1[C]	0.002	<0.001	<0.001	0.001	-	0.0010	<0.0010
Iron	mg/L	0.3[C]	<0.1	<0.1	<0.1	<0.1	-	<0.10	<0.10
Lead	mg/L	0.01_c[A]	0.0012	<0.0005	<0.0005	<0.0005	-	<0.00050	<0.00050
Magnesium	mg/L	n/v	26	24	25	24	-	20	21
Manganese	mg/L	0.05[C]	0.012	0.011	0.011	<0.002	-	<0.0020	<0.0020
Molybdenum	mg/L	n/v	<0.001	<0.001	<0.001	<0.001	-	<0.00050	<0.00050
Nickel	mg/L	n/v	0.001	<0.001	<0.001	<0.001	-	0.0010	<0.0010
Phosphorus	mg/L	n/v	<0.1	<0.1	<0.1	<0.1	-	<0.10	<0.10
Potassium	mg/L	n/v	0.8	0.7	0.7	0.8	-	0.68	0.72
Selenium	mg/L	0.01[A]	<0.002	<0.002	<0.002	<0.002	-	<0.0020	<0.0020
Silicon	mg/L	n/v	5.8	5.5	5.6	5.8	-	5.3	5.3
Silver	mg/L	n/v	<0.0001	<0.0001	<0.0001	<0.0001	-	<0.00010	<0.00010
Sodium	mg/L	200_g[C] 20_g[E]	5.1	4.8	4.8	5.3	-	3.5	3.6
Strontium	mg/L	n/v	0.11	0.11	0.11	0.12	-	0.086	0.10
Thallium	mg/L	n/v	<0.00005	<0.00005	<0.00005	<0.00005	-	<0.000050	<0.000050
Titanium	mg/L	n/v	<0.005	<0.005	<0.005	<0.005	-	<0.0050	<0.0050
Uranium	mg/L	0.02[A]	0.0002	0.0002	0.0002	0.0002	-	<0.00010	0.00019
Vanadium	mg/L	n/v	<0.001	<0.001	<0.001	<0.001	-	<0.00050	<0.00050
Zinc	mg/L	5[C]	0.014	0.009	0.007	0.006	-	0.0080	<0.0050

Notes:

ODWS	O. Reg 169/03 (January 2017) and Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines (MOE, 2006)
A	ODWS Table 2 - Chemical Standards, Maximum Acceptable Concentration
B	ODWS Table 2 - Chemical Standards, Interim Maximum Acceptable Concentration
C	ODWS Table 4 - Chemical/Physical Objectives and Guidelines, Aesthetic Objectives
D	ODWS Table 4 - Chemical/Physical Objectives and Guidelines, Operational Guidelines
E	ODWS Table 4 - Medical Officer of Health Reporting Limit
6.5[A]	Concentration exceeds the indicated standard.
15.2	Measured concentration was less than the applicable standard.
<0.50	Laboratory reporting limit was greater than the applicable standard.
<0.03	Analyte was not detected at a concentration greater than the laboratory reporting limit.
n/v	No standard/guideline value.
-	Parameter not analyzed / not available.
c	This standard applies to water at the point of consumption. Since lead is a component in some plumbing systems, first flush water may contain higher concentrations of lead than water that has been flushed for five minutes.
d	Where both nitrate and nitrite are present, the total of the two should not exceed 10 mg/L (as nitrogen).
CE g	The aesthetic objective for sodium in drinking water is 200 mg/L. The local Medical Officer of Health should be notified when the sodium concentration exceeds 20 mg/L so that this information may be communicated to local physicians for their use with patients on sodium restricted diets.
h	When sulfate levels exceed 500 mg/L, water may have a laxative effect on some people.

APPENDIX C:

Borehole Logs

Naylor Engineering Associates Ltd.
CONSULTING ENGINEERS

BOREHOLE: 12
Sheet 1 of 1

PROJECT Proposed Residential Subdivision
DATE 5 December 2002
JOB NO. 4500G01
LOCATION Activa Conservation Lands, Waterloo, Ontario
FIELD ENG/TECH RM

DEPTH (m)	DESCRIPTION	LEGEND	ELEV.	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES N-VALUE
	GROUND ELEVATION: 355.50					
0	TOPSOIL: dark brown silt, moist					
0.40	SILT: compact brown sandy silt, very moist		355	1	SS	21
1.50	SILT TILL: very stiff to hard brown clayey silt, trace sand, DTPL		354	2	SS	20
2.30	grey, trace gravel		353	3	SS	35
			352	4	SS	24
			351	5	SS	23
5.05	Borehole terminated at 5.05 m.					

SHEAR STRENGTH, kPa(ksf)
FV. NAT. ■ REM. □
UC ✣ PP ▲
50(1)100(2)150(3)200(4)
PENETRATION RESISTANCE
DYNAMIC CONE ✕
STANDARD PENETRATION ●
20 40 60 80

WATER CONTENT (%)
Wp W Wl
10 20 30

GROUNDWATER OBSERVATIONS & PIEZOMETER DETAILS

bentonite seal

13 mm pipe

native backfill

1.2 m slotted filter

At drilling completion, dry cave at 4.6 m.

December 12, 2002. Water level at 1.56 m (Elev. 353.94)

NOTES:

DRILLING METHOD: Solid Stem Augers

ENGINEER: RD

Naylor Engineering Associates Ltd
CONSULTING ENGINEERS

Borehole Number: 102

Ground Elevation: *362.72 m*

Project: *Groundwater Level Monitoring, Construction Phase*

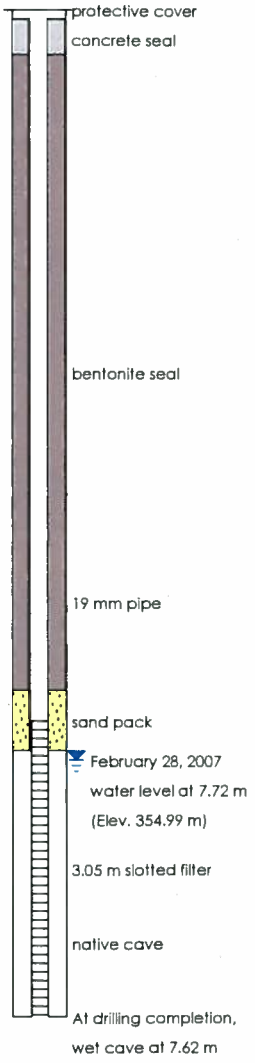
Job No.: *4500H1*

Location: *Activa Conservation Lands, Waterloo, Ontario*

Drill Date: *January 30, 2007*

Depth (m)	Description	Elevation (m)	Sample Number	Sample Type	N-Value
0.00	Ground Elevation	362.72			
0.00	***SAND:*** compact brown fine to medium sand, trace silt, damp	362.00			
1.00			1	SS	22
2.00		361.00			
3.00		360.00	2	SS	23
4.00		359.00			
5.00	dense	358.00	3	SS	51
6.00		357.00			
7.00		356.00	4	SS	46
8.00	moist	355.00	5	SS	31
9.00	saturated	354.00			
10.00		353.00	6	AS	
11.00	Borehole terminated at 10.36 m	352.00			
12.00		351.00			

Dynamic Cone: X 20 40 60 80 X
Standard Penetration: ● 20 40 60 80 ●
Shear Strength (PP) kPa: ▲ 50 100 150 200 ▲
Shear Strength (FV) kPa: ■ 50 100 150 200 ■
WP WL
Water Content (%): 10 20 30



Reviewed by: *CF*

Drill Method: *Solid Stem Auger*

Notes:

Field Tech.: *RM*

Sheet: *1 of 1*

Drafted by: *DC(01a)*

Naylor Engineering Associates Ltd.
CONSULTING ENGINEERS

Borehole Number: 103

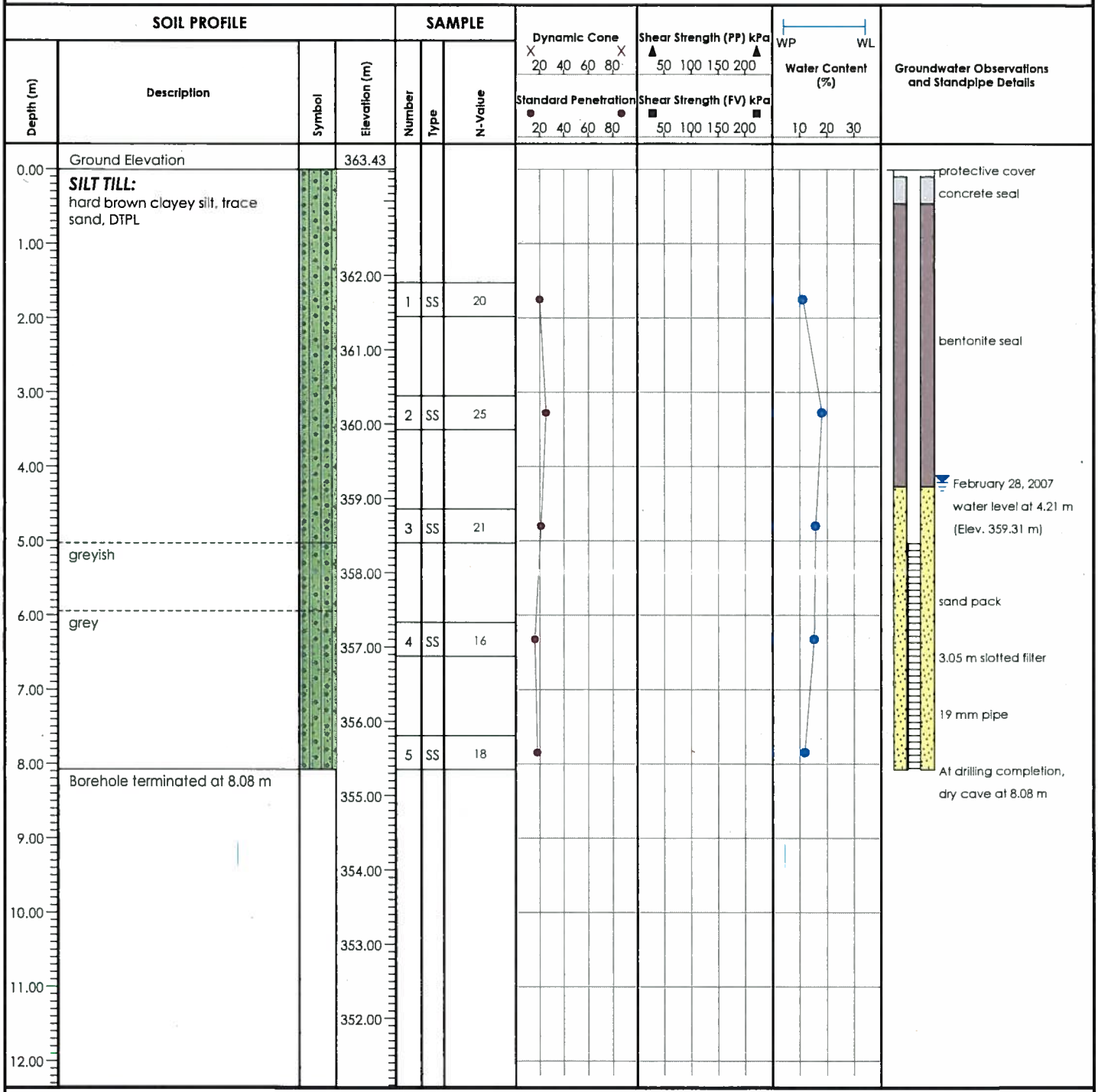
Ground Elevation: *363.43 m*

Project: *Groundwater Level Monitoring, Construction Phase*

Job No.: *4500H1*

Location: *Activa Conservation Lands, Waterloo, Ontario*

Drill Date: *January 30, 2007*



Reviewed by: *CF*

Drill Method: *Solid Stem Auger*

Notes:

Field Tech.: *RM*

Sheet: *1 of 1*

Drafted by: *DC(01a)*

Naylor Engineering Associates Ltd
CONSULTING ENGINEERS

Borehole Number: 104

Ground Elevation: *362.72 m*

Project: *Groundwater Level Monitoring, Construction Phase*

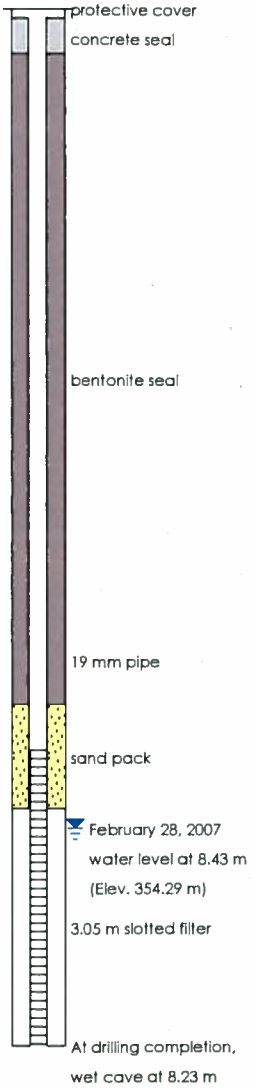
Job No.: *4500H1*

Location: *Activa Conservation Lands, Waterloo, Ontario*

Drill Date: *February 1, 2007*

Depth (m)	Description	Elevation (m)	Sample Number	Sample Type	N-Value
0.00	Ground Elevation	362.72			
	FILL: dark brown silt (topsoil), moist	362.00			
1.00	**SILT TILL:** hard brown clayey silt, trace sand, DTPL; some thin sand seams, damp	361.00	1	SS	22
2.00		360.00	2	SS	29
3.00		359.00			
4.00	**SAND:** compact brown fine to medium sand, trace silt, damp	358.00	3	SS	18
5.00		357.00			
6.00		356.00	4	SS	21
7.00		355.00			
8.00			5	SS	22
	saturated	354.00			
9.00		353.00	6	SS	19
10.00		352.00	7	AS	
11.00	Borehole terminated at 10.67 m	351.00			
12.00					

Dynamic Cone (X): 20 40 60 80
Standard Penetration (●): 20 40 60 80
Shear Strength (PP) kPa (▲): 50 100 150 200
Shear Strength (FV) kPa (■): 50 100 150 200
Water Content (%): WP WL; 10 20 30



Reviewed by: *CF*

Drill Method: *Solid Stem Auger*

Notes:

Field Tech.: *RM*

Sheet: *1 of 1*

Drafted by: *DC(01a)*

Naylor Engineering Associates Ltd
CONSULTING ENGINEERS

Borehole Number: 105

Ground Elevation: *362.70 m**

Project: *Groundwater Level Monitoring, Construction Phase*

Job No.: *4500H1*

Location: *Activa Conservation Lands, Waterloo, Ontario*

Drill Date: *February 1, 2007*

Depth (m)	Description	Elevation (m)	Number	Type	N-Value
0.00	Ground Elevation	362.70			
	FILL: brown clayey silt, APL				
1.00	***SILT:*** compact brown fine sandy silt, moist	362.00			
		361.00	1	SS	13
2.00	***SAND:*** dense brown silty fine to medium sand, damp				
3.00		360.00	2	SS	31
4.00		359.00			
	saturated	358.00	3	SS	29
5.00					
6.00		357.00	4	SS	20
	Borehole terminated at 6.55 m	356.00			
7.00					
8.00		355.00			
9.00		354.00			
10.00		353.00			
11.00		352.00			
12.00		351.00			

Dynamic Cone (X) 20 40 60 80
Standard Penetration (●) 20 40 60 80
Shear Strength (PP) kPa (▲) 50 100 150 200
Shear Strength (FV) kPa (■) 50 100 150 200
WP WL
Water Content (%) 10 20 30

Groundwater Observations and Standpipe Details

- protective cover
- concrete seal
- bentonite seal
- 19 mm pipe
- sand pack
- February 28, 2007 water level at 4.28 m (Elev. 353.83 m)
- 3.05 m slotted filter
- native cave
- At drilling completion, wet cave at 4.57 m

Reviewed by: *CF*

Drill Method: *Solid Stem Auger*

Notes:

Field Tech.: *RM*

Sheet: *1 of 1*

Drafted by: *DC(01a)*

*Ground Elevation was resurveyed by Stantec in July 2017 as 358.03 m AMSL

Monitoring Well: MW7-10

Project:	North Waterloo Subwatershed Study	**Drilling method:**	Track Mount, CME75, Hollow Stem Auger
Client:		**Date started/completed:**	18-Mar-2010
Location:	North Waterloo, ON	**Ground surface elevation:**	n/a
Number:	160330875	**Top of casing elevation:**	n/a
Field investigator:	A.Vandenhoff	**Easting:**	n/a
Contractor:	ProCore	**Northing:**	n/a

SUBSURFACE PROFILE				SAMPLE DETAILS				WELL DETAILS	
Depth (ft)	Depth (m)	Graphic Log	Lithologic Description	Depth (m BGS)	Sample Number	Sample Type	N Value	Recovery	Well Diagram / Description
			Ground Surface						
			TOPSOIL dark brown	0.00					Concrete
			CLAYEY SILT trace gravel, light brown, firm to stiff, moist	0.25	1	SS	1-1-2-3 (3)	19" 79%	
					2	SS	2-3-5-5 (8)	13" 54%	52 mm Schedule 40 PVC casing
5	2		SAND fine to medium grained sand, trace silt, trace gravel, light reddish brown, loose, moist	1.22	3	SS	6-1-4-5 (5)	11" 46%	
			SILT trace fine to coarse sand, trace gravel, stiff, light brown, moist	2.44	4	SS	1-5-7-12 (12)	15" 63%	Holeplug
10	4		becoming clayey at 3.1 m BGS		5	SS	2-5-6-10 (11)	24" 100%	
15			SAND fine to medium grained, light brown, compact, moist	4.57	6	SS	4-14-20-24 (34)	18" 75%	Top of sand (5.2 m BGS)
20	6		becoming wet at 5.2 to 6.1 m BGS		7	SS	8-20-22->50 (>42)	24" 100%	Top of screen (5.8 m BGS) No.2 Silica Sand No.10 Slot PVC screen 50 mm diameter Bottom of screen (7.3 m BGS) Natural Cave
25	8				8	SS	9-20-32-39 (52)	24" 100%	
			End of Monitoring Well	8.23					

Screen Interval: 5.79 - 7.32 m BGS
Sand Pack Interval: 5.18 - 7.32 m BGS
Well Seal Interval: 0.30 - 5.18 m BGS

Notes:
m AMSL - metres above mean sea level
m BGS - metres below ground surface
m BTOC - metres below top of casing
SS - split-spoon sample
n/a - not available

Drawn By/Checked By: OR/LV

Stantec

STANTEC BOREHOLE AND WELL 160330875 - DPS.GPJ EQUIS DATA TEMPLATE.GDT 11/17/10

Stantec

BOREHOLE RECORD

N: 4 815 067 E: 533 138

MW01-18

CLIENT Activa

PROJECT No. 60308671

LOCATION Conservation Drive, Waterloo

DATUM

DATES: BORING Jan 18, 2018

WATER LEVEL Feb 16, 2018

TPC ELEVATION 356.975

DEPTH (m)	ELEVATION (m)	STRATA DESCRIPTION	DEPTH (ft)	SAMPLES TYPE	NUMBER	RECOVERY (mm) TCR(%) / SCR(%)	N-VALUE OR RQD(%)
0	356.2	**Snow Covered ~ 50 mm**	0				
		FILL: brown sand - some silt, organics and topsoil - damp to moist	1	SS	1	460/610	2
1			2				
			3	SS	2	250/610	8
			4				
			5				
2			6	SS	3	51/610	2
	353.9		7				
		Loose to compact brown to light grey SILT (ML) - trace sand and clay - very wet	8	SS	4	410/610	7
			9				
3			10				
			11	SS	5	51/610	10
			12				
4			13	SS	6	610/610	18
			14				
			15				
			16	SS	7	510/610	23
5	350.9		17				
		- Borehole terminated at 5.3 m below existing grade. - Groundwater level at elevation 354.06 m on February 16, 2018. - Monitoring Well installed with screen from 3.8 m to 5.3 m.	18				
			19				
6			20				
			21				
			22				
7			23				
			24				
			25				
8			26				
			27				
			28				
9			29				
			30				
			31				
10			32				

UNDRAINED SHEAR STRENGTH (kPa)

50 100 150 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC CONE PENETRATION TEST, BLOWS/0.3m ▼

STANDARD PENETRATION TEST, BLOWS/0.3m ●

REMARKS & GRAIN SIZE DISTRIBUTION (%)

10 20 30 40 50 60 70 80 90 100

GR SA SI CL

□ Field Vane Test, kPa

■ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

Stantec

BOREHOLE RECORD

N: 4 815 022 E: 533 165

MW02-18

CLIENT Activa

PROJECT No. 60308671

LOCATION Conservation Drive, Waterloo

DATUM

DATES: BORING Jan 18, 2018

WATER LEVEL Feb 16, 2018

TPC ELEVATION 354.239

DEPTH (m)	ELEVATION (m)	STRATA DESCRIPTION	STRATA PLOT	WATER LEVEL	DEPTH (ft)	SAMPLES TYPE	NUMBER	RECOVERY (mm) TCR(%) / SCR(%)	N-VALUE OR RQD(%)
0	353.5	**Snow/Vegetation**			0				
		TOPSOIL: Black			1	SS	1	51/610	2
	352.9				2				
1		Soft brown SILTY CLAY (CL-ML) - organics above 0.9 m - moist to wet		▽	3	SS	2	300/610	3
	352.0				4				
		Compact brown to light grey silt (ML) TILL - trace sand, clay and fine gravel - moist to wet - some clay below 2.3 m - very wet below 2.4 m			5				
2					6	SS	3	610/610	10
					7				
					8	SS	4	610/610	14
					9				
3	350.5				10				
		Stiff grey SILT (ML) - some clay, trace sand - wet			11	SS	5	610/610	11
					12				
					13				
4					14	SS	6	510/610	16
	348.9				15				
		- Borehole terminated at 4.6 m below existing grade. - Groundwater level at elevation 352.58 m on February 16, 2018. - Monitoring Well Installed with screen from 3.0 m to 4.6 m.			16				
5					17				
					18				
					19				
6					20				
					21				
					22				
7					23				
					24				
					25				
8					26				
					27				
					28				
9					29				
					30				
					31				
10					32				

UNDRAINED SHEAR STRENGTH (kPa)

50 100 150 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC CONE PENETRATION TEST, BLOWS/0.3m ▼

STANDARD PENETRATION TEST, BLOWS/0.3m ●

REMARKS & GRAIN SIZE DISTRIBUTION (%)

10 20 30 40 50 60 70 80 90 100

GR SA SI CL

□ Field Vane Test, kPa

■ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

Stantec

BOREHOLE RECORD

N: 4 815 102 E: 533 210

MW03-18

CLIENT Activa

PROJECT No. 60308671

LOCATION Conservation Drive, Waterloo

DATUM

DATES: BORING Jan 18, 2018

WATER LEVEL Feb 16, 2018

TPC ELEVATION 357.764

DEPTH (m)	ELEVATION (m)	STRATA DESCRIPTION	DEPTH (ft)	SAMPLES TYPE	NUMBER	RECOVERY (mm) TCR(%) / SCR(%)	N-VALUE OR RQD(%)
0	356.9	**Snow Covered ~ 100 mm**	0				
		TOPSOIL: dark brown sandy silt - some organics	1	SS	1	300/610	
	356.0		2				
1		Stiff light brown SILT (ML) - some sand and clay	3	SS	2	410/610	9
	355.4	- wet	4				
		Stiff to very stiff light brown silt (ML) TILL - some clay and sand, trace gravel - moist to wet	5				
2			6	SS	3	610/610	16
			7				
			8	SS	4	610/610	19
3			9				
			10				
			11	SS	5	610/610	21
			12				
4		- grey	13	SS	6	610/610	15
			14				
			15				
			16	SS	7	610/610	12
5	351.6		17				
		- Borehole terminated at 5.3 m below existing grade. - Groundwater level at elevation 356.21 m on February 16, 2018. - Monitoring Well Installed from 3.8 m to 5.3 m.	18				
			19				
6			20				
			21				
			22				
7			23				
			24				
			25				
8			26				
			27				
			28				
9			29				
			30				
			31				
10			32				

UNDRAINED SHEAR STRENGTH (kPa)

50 100 150 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC CONE PENETRATION TEST, BLOWS/0.3m ▼

STANDARD PENETRATION TEST, BLOWS/0.3m ●

REMARKS & GRAIN SIZE DISTRIBUTION (%)

10 20 30 40 50 60 70 80 90 100

GR SA SI CL

□ Field Vane Test, kPa

■ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

Stantec

BOREHOLE RECORD

N: 4 815 054 E: 533 234

MW04-18

CLIENT Activa — PROJECT No. 60308671

LOCATION Conservation Drive, Waterloo — DATUM

DATES: BORING Jan 18, 2018 — WATER LEVEL Feb 16, 2018 — TPC ELEVATION 355.472

DEPTH (m)	ELEVATION (m)	STRATA DESCRIPTION	DEPTH (ft)	SAMPLES TYPE	NUMBER	RECOVERY (mm) TCR(%) / SCR(%)	N-VALUE OR RQD(%)
0	**354.6**	**Snow/Vegetation**	0				
	354.3	TOPSOIL: dark brown sandy silt	1	SS	1	510/610	5
		Compact to loose brown SILT (ML) - trace sand - wet	2				
1			3	SS	2	150/610	10
			4				
			5				
2			6	SS	3	300/610	11
			7				
			8	SS	4	510/610	9
			9				
3	351.6		10				
		Compact brown SAND (SW-SM) - some silt - wet	11	SS	5	510/610	12
4			12				
			13				
	350.0		14				
		Stiff grey silt (ML) TILL - trace clay, sand and fine gravel - very wet	15				
5			16	SS	6	510/610	9
	349.3		17				
		- Borehole terminated at 5.3 m below existing grade. - Groundwater level at elevation 353.78 m on February 16, 2018. - Monitoring Well installed with screen from 3.8 m to 5.3 m.	18				
6			19				
			20				
			21				
			22				
7			23				
			24				
			25				
			26				
8			27				
			28				
			29				
			30				
9			31				
			32				
10							

UNDRAINED SHEAR STRENGTH (kPa)

50 100 150 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC CONE PENETRATION TEST, BLOWS/0.3m ▼

STANDARD PENETRATION TEST, BLOWS/0.3m ●

REMARKS & GRAIN SIZE DISTRIBUTION (%)

10 20 30 40 50 60 70 80 90 100

GR SA SI CL

□ Field Vane Test, kPa

■ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

Stantec

BOREHOLE RECORD

N: 4 815 149 E: 533 307

MW05-18

CLIENT Activa

PROJECT No. 60308671

LOCATION Conservation Drive, Waterloo

DATUM

DATES: BORING Jan 17, 2018

WATER LEVEL Feb 16, 2018

TPC ELEVATION 362.107

DEPTH (m)	ELEVATION (m)	STRATA DESCRIPTION	DEPTH (ft)	SAMPLES TYPE	NUMBER	RECOVERY (mm) TCR(%) / SCR(%)	N-VALUE OR RQD(%)
0	361.4	**Snow Covered ~ 50 mm**	0				
0		FILL: Dark brown sandy silt topsoil - moist	0–2	SS	1	410/610	14
1			3–4	SS	2	510/610	6
2	359.1		6–7	SS	3	610/610	4
		Compact light brown fine SAND (SW) - trace silt above 7.5 m - some silt below 7.5 m - damp	8–9	SS	4	610/610	12
3			10–12	SS	5	610/610	16
4			13–15	SS	6	460/610	24
5			16–17	SS	7	460/610	30
6		- moist to wet	18–20	SS	8	610/610	26
			21–22	SS	9	610/610	16
7		▽ - saturated	23–25	SS	10	510/610	18
8	353.2		26–27	SS	11	510/610	6
		- Borehole terminated at 7.6 m below existing grade. - Groundwater level at elevation 354.51 m on February 16, 2018. - Monitoring Well Installed with screen from 6.1 m to 7.6 m.	28–32				
9							
10							

UNDRAINED SHEAR STRENGTH (kPa)

50 100 150 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC CONE PENETRATION TEST, BLOWS/0.3m ▼

STANDARD PENETRATION TEST, BLOWS/0.3m ●

REMARKS & GRAIN SIZE DISTRIBUTION (%)

10 20 30 40 50 60 70 80 90 100

GR SA SI CL

□ Field Vane Test, kPa

■ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

Stantec

BOREHOLE RECORD

N: 4 815 139 E: 533 406

MW06-18

CLIENT Activa PROJECT No. 60308671

LOCATION Conservation Drive, Waterloo DATUM

DATES: BORING Jan 17, 2018 WATER LEVEL Feb 16, 2018 TPC ELEVATION 356.265

DEPTH (m)	ELEVATION (m)	STRATA DESCRIPTION	TYPE	NUMBER	RECOVERY (mm) TCR(%) / SCR(%)	N-VALUE OR RQD(%)
0	355.4	**Snow/ice Covered**				
0		FILL: Dark brown sandy topsoil - wet	SS	1	510/610	5
1			SS	2	610/610	4
	353.9					
2		Stiff light brown/grey SILT (ML) - wet	SS	3	300/610	14
	353.1					
		Compact light brown SILTY SAND (SM) - wet	SS	4	300/610	15
3	351.7		SS	5	610/610	29
4		- Borehole terminated at 3.0 m below existing grade. - Groundwater level at elevation 353.74 m on February 16, 2018. - Monitoring Well installed with screen from 1.5 m to 3.0 m.				
5						
6						
7						
8						
9						
10						

DEPTH (ft): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32

SAMPLES

UNDRAINED SHEAR STRENGTH (kPa)

50 100 150 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC CONE PENETRATION TEST, BLOWS/0.3m

STANDARD PENETRATION TEST, BLOWS/0.3m

REMARKS & GRAIN SIZE DISTRIBUTION (%)

10 20 30 40 50 60 70 80 90 100

GR SA SI CL

□ Field Vane Test, kPa

■ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

Stantec

BOREHOLE RECORD

N: 4 815 211 E: 533 438

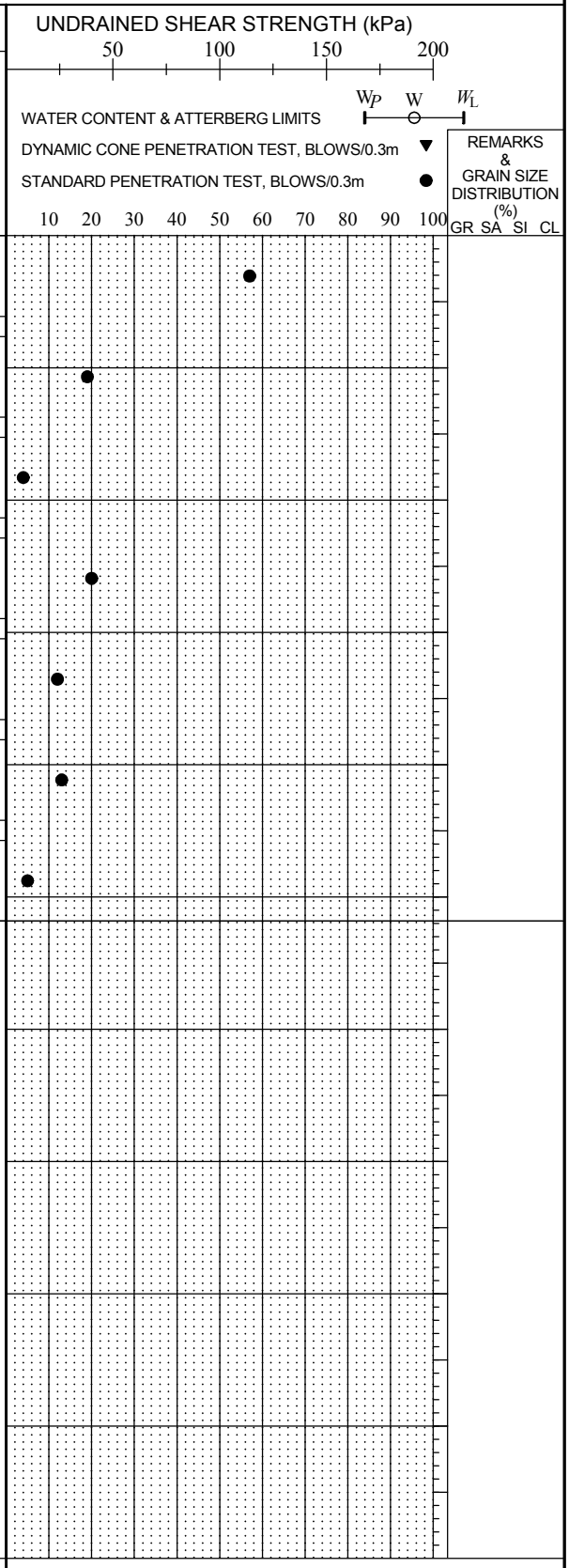
MW07-18

CLIENT Activa — PROJECT No. 60308671

LOCATION Conservation Drive, Waterloo — DATUM

DATES: BORING Jan 17, 2018 — WATER LEVEL Feb 16, 2018 — TPC ELEVATION 360.891

DEPTH (m)	ELEVATION (m)	STRATA DESCRIPTION	DEPTH (ft)	TYPE	NUMBER	RECOVERY (mm) TCR(%) / SCR(%)	N-VALUE OR RQD(%)
0	360.1	**Snow Covered ~ 50 mm**	0				
		FILL: silt with some sand and occasional gravel, - frozen at time of investigation	1	SS	1	610/610	57
	359.3		2				
1		FILL: light brown to grey sand - some silt - moist	3	SS	2	460/610	19
			4				
			5				
2			6	SS	3	150/610	4
	357.8		7				
		FILL: brown silt, some sand and trace gravel - moist	8	SS	4	360/610	20
			9				
3			10				
			11	SS	5	460/610	12
	356.1		12				
4		FILL: dark brown silty topsoil	13	SS	6	510/610	13
			14				
		▽	15				
			16	SS	7	510/610	5
5	354.9		17				
		- Borehole terminated at 4.6 m below existing grade. - Groundwater level at elevation 355.41 m on February 16, 2018. - Monitoring Well Installed from 3.1 m to 4.6 m.	18				
			19				
6			20				
			21				
			22				
7			23				
			24				
			25				
8			26				
			27				
			28				
9			29				
			30				
			31				
10			32				



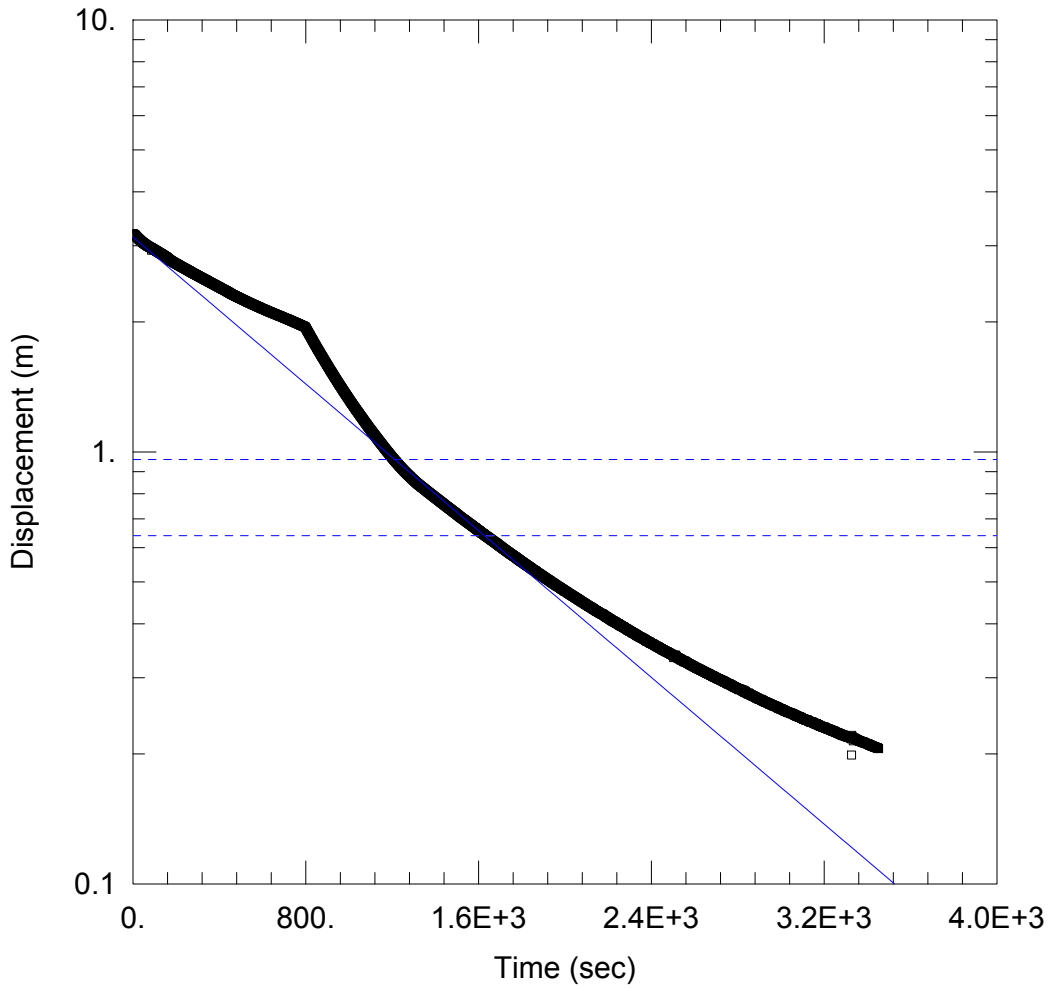
□ Field Vane Test, kPa

■ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

APPENDIX D:

Hydraulic Conductivity Solutions



MW01-18

Data Set: \...\60308671_MW01_18_20180525_CD_DS_JK.aqt
Date: 06/04/18 Time: 16:15:14

PROJECT INFORMATION

Company: Stantec Consulting
Client: Activa
Project: 60308671
Location: Waterloo, ON
Test Well: MW01-18
Test Date: May 25, 2018

AQUIFER DATA

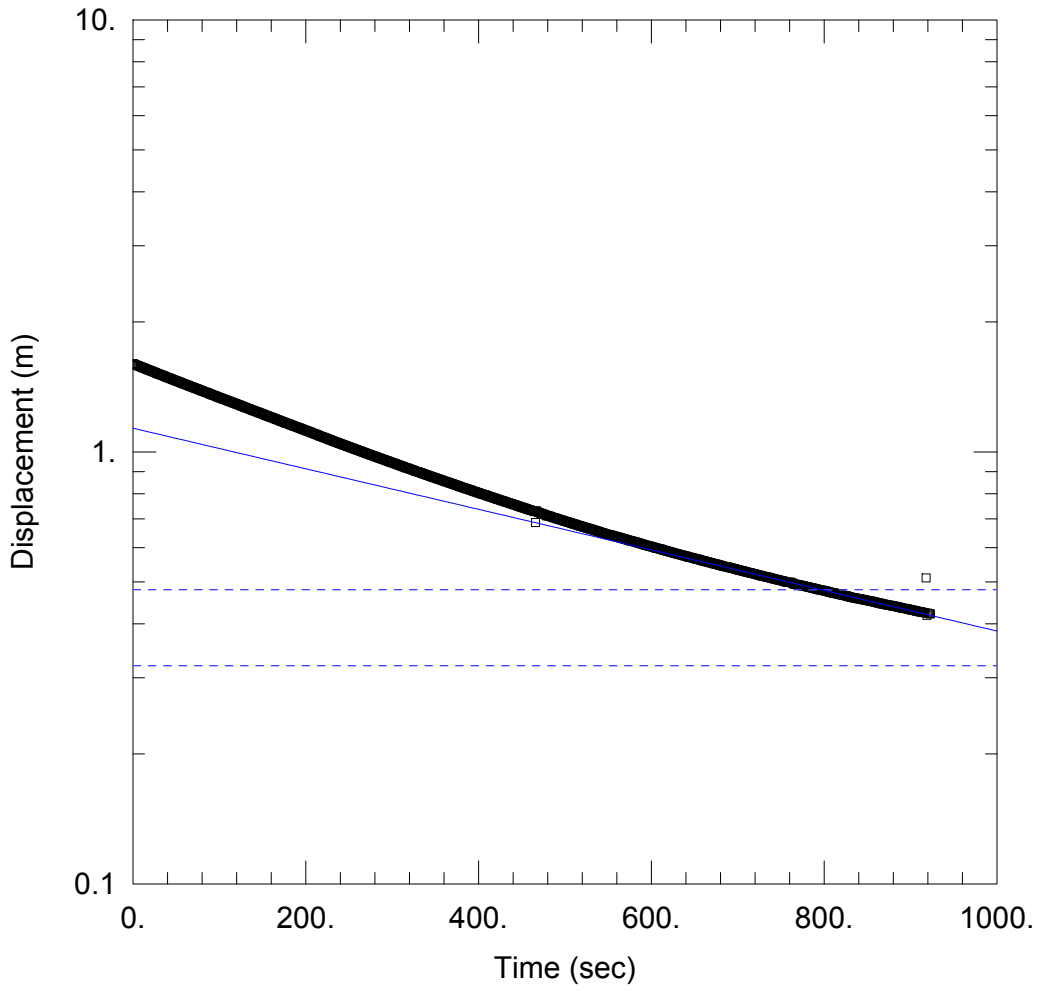
Saturated Thickness: 3.45 m
Anisotropy Ratio (Kz/Kr): 0.25

WELL DATA (MW01-18)

Initial Displacement: 3.2 m
Total Well Penetration Depth: 3.47 m
Casing Radius: 0.0254 m
Static Water Column Height: 3.45 m
Screen Length: 1.52 m
Well Radius: 0.105 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 6.3E-7 m/sec
y0 = 3.141 m



MW02-18

Data Set: \...\60308671_MW02_18_20180525_DS_JK.aqt
Date: 06/04/18 Time: 16:26:45

PROJECT INFORMATION

Company: Stantec
Client: Activa
Project: 60308671
Location: Conservation Drive, Waterloo
Test Well: MW02-18
Test Date: 2018/05/25

AQUIFER DATA

Saturated Thickness: 1.6 m Anisotropy Ratio (Kz/Kr): 0.25

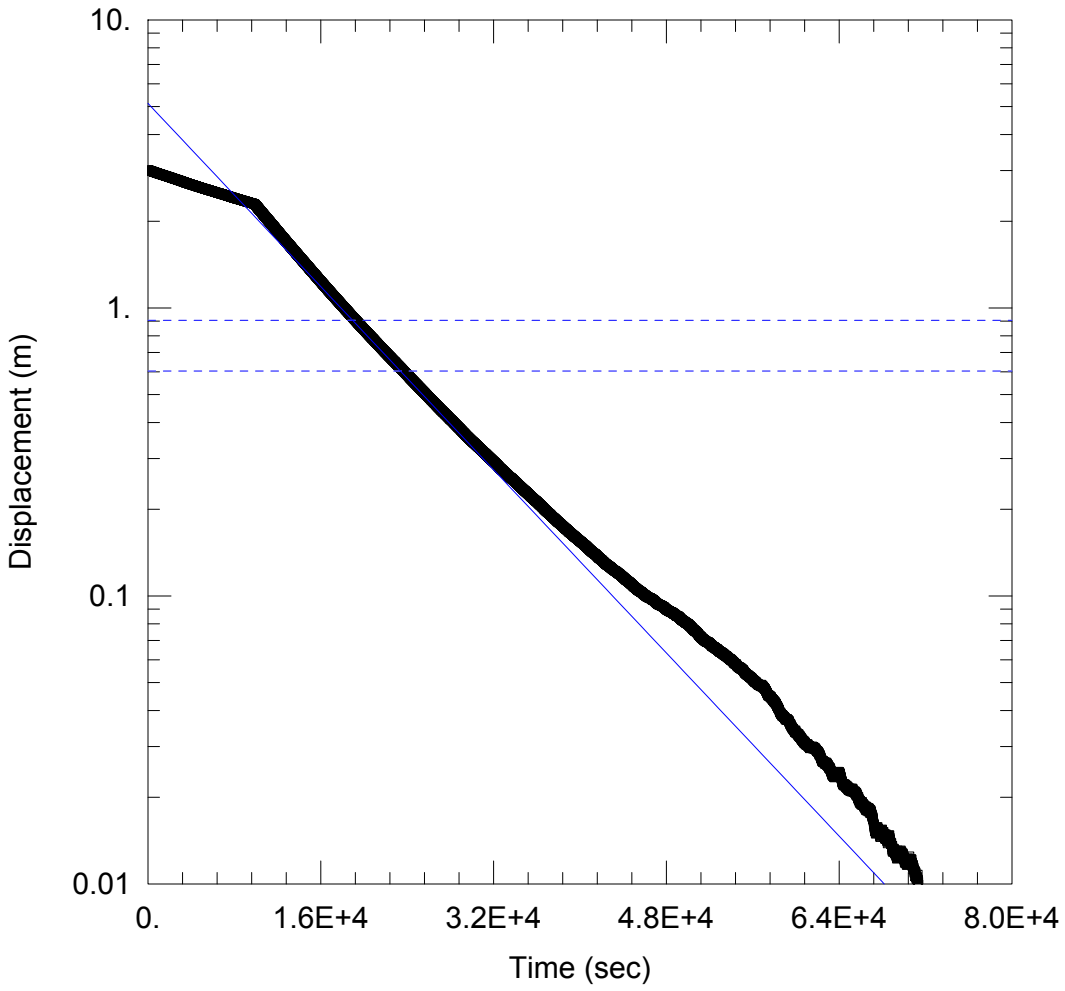
WELL DATA (MW02-18)

Initial Displacement: 1.599 m
Total Well Penetration Depth: 1.6 m
Casing Radius: 0.0254 m
Static Water Column Height: 3.57 m
Screen Length: 1.52 m
Well Radius: 0.105 m

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice

K = 5.9E-7 m/sec
y0 = 1.135 m



MW03-18

Data Set: \...\60308671_MW03_18_20180525_CD_JK.aqt
Date: 06/05/18 Time: 08:47:17

PROJECT INFORMATION

Company: Stantec Consulting
Client: Activa
Project: 60308671
Location: Waterloo, ON
Test Well: MW03-18
Test Date: May 25, 2018

AQUIFER DATA

Saturated Thickness: 3.8 m Anisotropy Ratio (Kz/Kr): 0.25

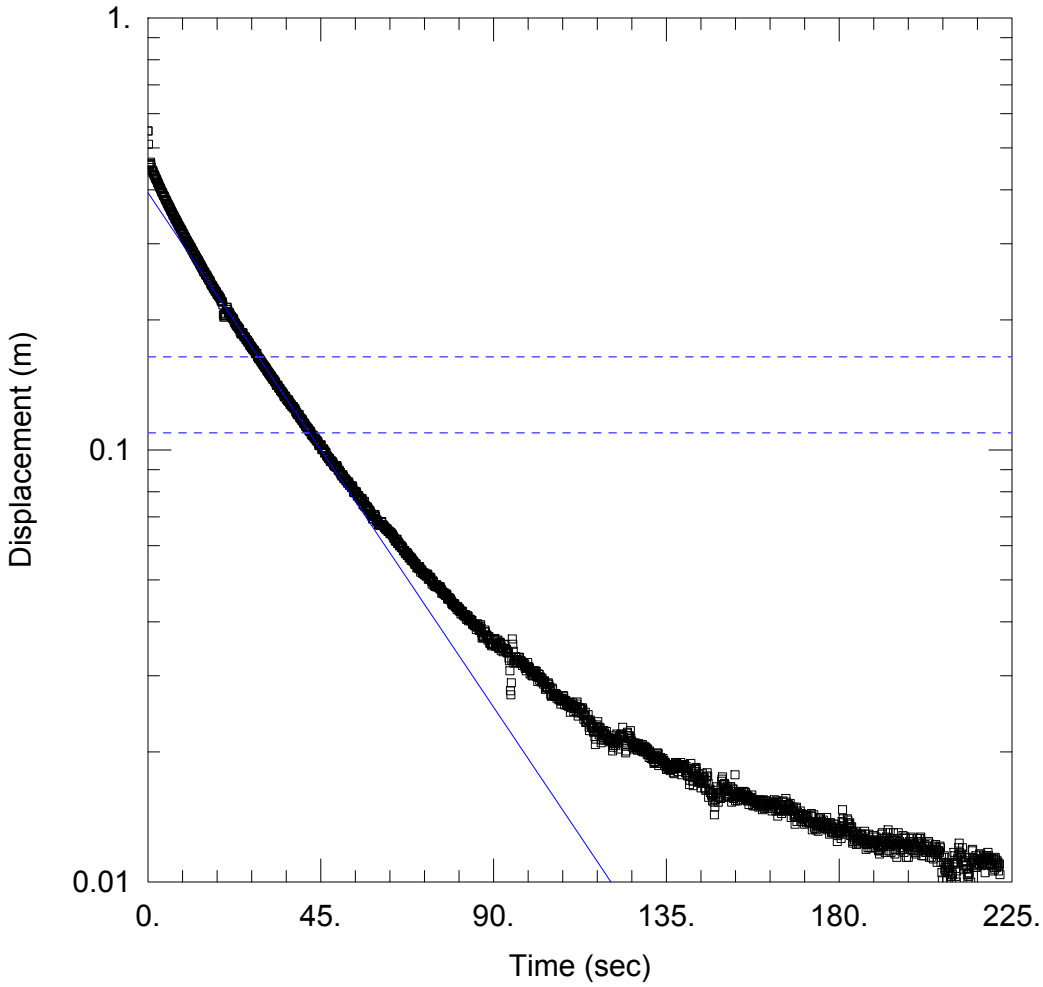
WELL DATA (MW03-18)

Initial Displacement: 3.018 m
Total Well Penetration Depth: 3.8 m
Casing Radius: 0.0254 m
Static Water Column Height: 3.8 m
Screen Length: 1.52 m
Well Radius: 0.105 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 6.0E-8 m/sec
y0 = 5.129 m



MW04-18 TEST 1

Data Set: \...\60308671_MW04_18_test1_20180525_DS_JK.aqt
Date: 06/05/18 Time: 09:31:49

PROJECT INFORMATION

Company: Stantec
Client: Activa
Project: 60308671
Location: Conservation Drive, Waterloo
Test Well: MW04-18
Test Date: 2018/05/25

AQUIFER DATA

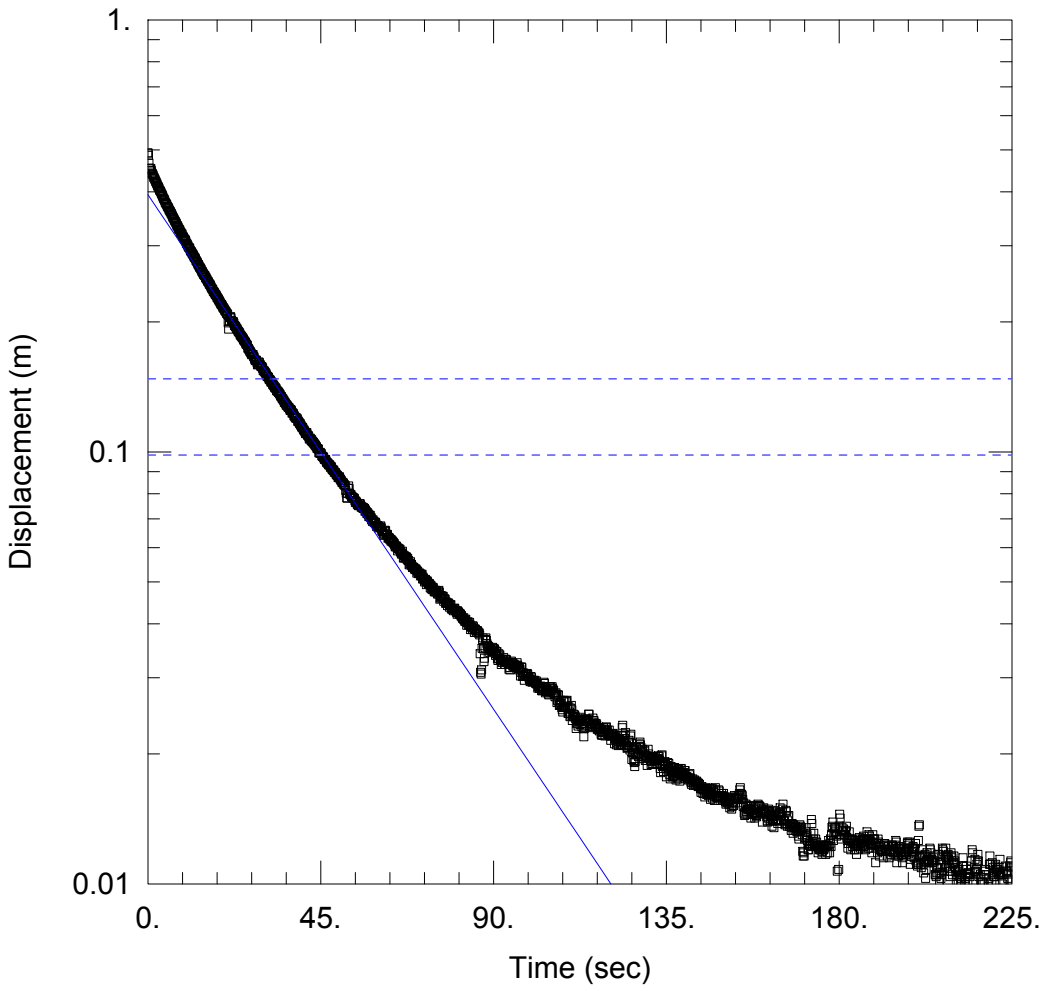
Saturated Thickness: 0.77 m
Anisotropy Ratio (Kz/Kr): 0.25

WELL DATA (MW04-18)

Initial Displacement: 0.5474 m
Total Well Penetration Depth: 3.85 m
Casing Radius: 0.0254 m
Static Water Column Height: 4.94 m
Screen Length: 0.77 m
Well Radius: 0.105 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 2.8E-5 m/sec
y0 = 0.3938 m



MW04-18 TEST 2

Data Set: \...\60308671_MW04_18_test2_20180525_DS_JK.aqt
Date: 06/05/18 Time: 09:39:49

PROJECT INFORMATION

Company: Stantec
Client: Activa
Project: 60308671
Location: Conservation Drive, Waterloo
Test Well: MW04-18
Test Date: 2018/05/25

AQUIFER DATA

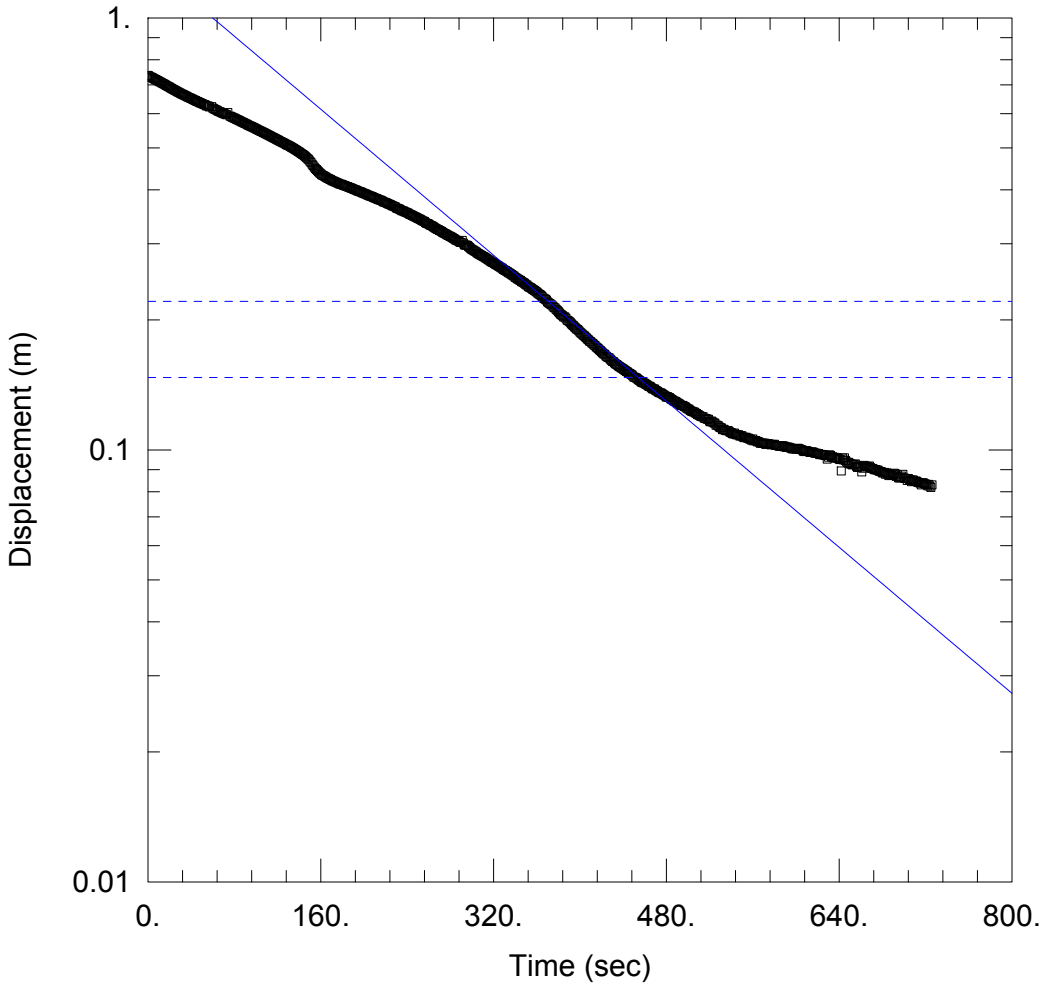
Saturated Thickness: 0.77 m
Anisotropy Ratio (Kz/Kr): 0.25

WELL DATA (MW04-18)

Initial Displacement: 0.4919 m
Total Well Penetration Depth: 3.85 m
Casing Radius: 0.0254 m
Static Water Column Height: 4.94 m
Screen Length: 0.77 m
Well Radius: 0.105 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 2.8E-5 m/sec
y0 = 0.3938 m



MW06-18

Data Set: \...\60308671_MW06_18_20180525_CD_DS_JK.aqt
Date: 06/05/18 Time: 09:52:38

PROJECT INFORMATION

Company: Stantec
Client: Activa
Project: 60308671
Location: Conservation Drive, Waterloo
Test Well: MW06-18
Test Date: 2018/05/25

AQUIFER DATA

Saturated Thickness: 1.6 m Anisotropy Ratio (Kz/Kr): 0.3

WELL DATA (MW06-18)

Initial Displacement: 0.7357 m
Total Well Penetration Depth: 1.6 m
Casing Radius: 0.0254 m
Static Water Column Height: 1.6 m
Screen Length: 1.52 m
Well Radius: 0.105 m
Gravel Pack Porosity: 0.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 1.5E-5 m/sec
y0 = 1.339 m

APPENDIX E:

GRIN Mapping



Grand River Conservation Authority

Date: Sep 29, 2019

Vertical Hydraulic Gradients

Legend

- Municipal Boundary (GRCA)
- Watercourse - Local (GRCA)
- Park - Local (GRCA)
- Waterbody - Local (GRCA)

Hydraulic Gradient (GRCA)

- Upward
- Downward

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Disclaimer: This map is for illustrative purposes only. Information contained herein is not a substitute for professional review or a site survey and is subject to change without notice. The Grand River Conservation Authority takes no responsibility for, nor guarantees, the accuracy of the information contained on this map. Any interpretations or conclusions drawn from this map are the sole responsibility of the user.
The source for each data layer is shown in parentheses in the map legend. For a complete listing of sources and citations go to: https://maps.grandriver.ca/Sources-and-Citations.pdf

0 35 70 140 210 Metres

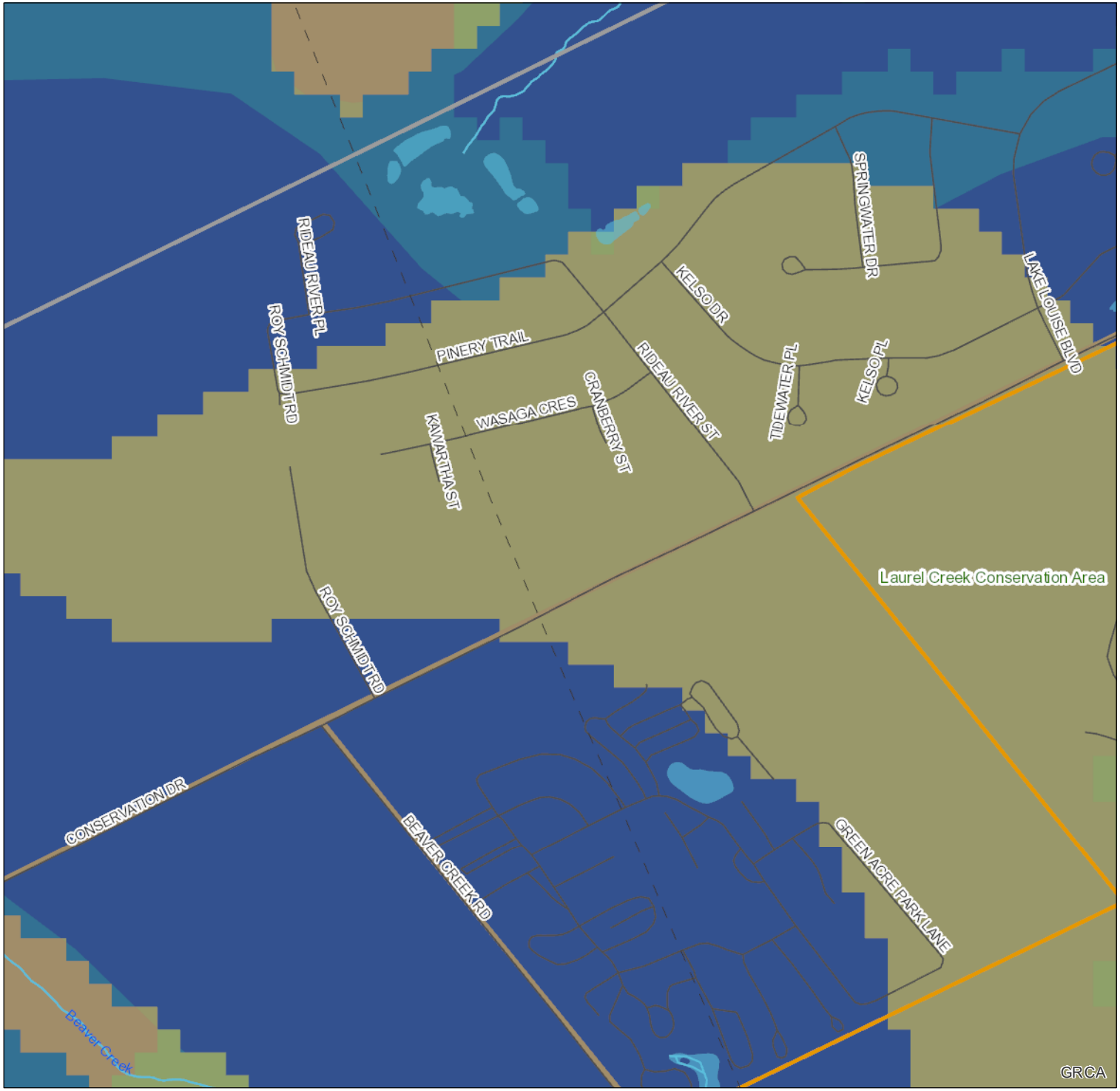
N

Map Centre (UTM NAD83 z17): 533,316.81 4,815,163.28

This map is not to be used for navigation

NAD 1983 UTM Zone 17N

Scale: 6,130



Grand River Conservation Authority

Date: Sep 29, 2019

Average Annual Recharge

Legend

- Municipal Boundary (GRCA)
- Watercourse - Local (GRCA)
- Park - Local (GRCA)
- Waterbody - Local (GRCA)

Average Annual Recharge (GRCA)

- less than 50 mm/yr
- 50 - 100
- 100 - 200
- 200 - 300
- 300 - 400
- > 400

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The source for each data layer is shown in parentheses in the map legend. For a complete listing of sources and citations go to: https://maps.grandriver.ca/Sources-and-Citations.pdf

0 35 70 140 210 Metres

N

Map Centre (UTM NAD83 z17): 533,316.81 4,815,138.09

This map is not to be used for navigation

NAD 1983 UTM Zone 17N

Scale: 6,130

APPENDIX F:

Dewatering Calculations

Dupuit Forcheimer Equation - Trench/Linear Excavation

To calculate flow from a line source in an unconfined aquifer using a derivation of the Dupuit-Forcheimer equation, and assuming a trench with flow from both sides including flow from ends of trench, where each end of the trench is treated as one half of a circular well with radial flow:

$$Q = \frac{2xK\left(H^2 - {h_w}^2\right)}{2L} + \frac{\pi K(H^2 - h^2)}{\ln\frac{R_o}{R_s}}$$

Where:

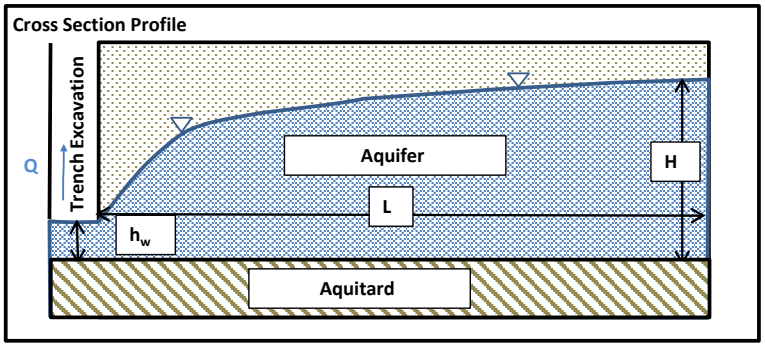
- Q = pumping rate in m^3/s
- K = hydraulic conductivity in m/s
- H = hydraulic head of the original water table (m)
- h_w = hydraulic head at the base of the trench (m)
- R_o = radius of influence at end of trench (m)
- L = equivalent radius of influence for a line source (m) from centre of the excavation
- x = length of the trench (m)
- R_s = equivalent radius of the dewatering system / trench (m)

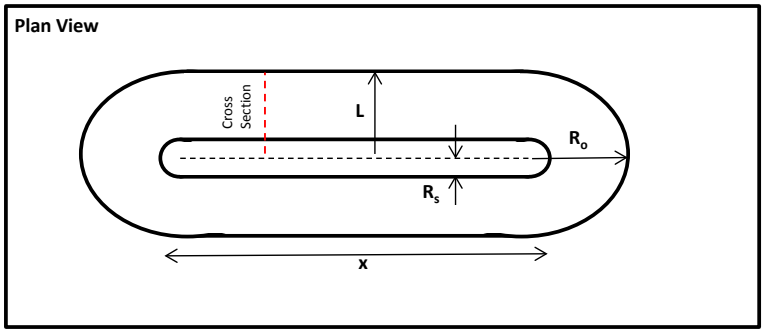
The equivalent radius of influence (R_o) for a point source is approximated using the Sichart and Kryieleis method:

$$R_o = R_w + 3000(H - h_w)\sqrt{K}$$

and from R_o, the equivalent radius of influence (L) for a line source can be approximated by:

$$L = \frac{R_o}{2}$$





Calculations:

K =	3.3E-05	m/s	x =	100	m	Q=	0.002850763 m^3/s
H =	5.2	m	R_s =	8	m		**246,306 L/day**
h_w =	4.6	m	Base of Aquifer	348.9	m AMSL		
R_o =	18.3	m	Static Water Level	354.1	m AMSL		
L =	9.2	m	Elevation requiring dewatering	353.5	m AMSL		

Equations obtained from Powers, J.P., A.B. Corwin, P.C. Schmall, and W.E. Kaeck, 2007. Construction Dewatering and Groundwater Control, New Methods and Applications. John Wiley & Sons, Inc., 3rd Edition.

Location	GS Elev.	High Water Level		Equation Parameters (m AMSL)			Total Water Level Drop	Radius of Pumping Influence (m)		Pumping Volume (L/day)
	(m AMSL)	(m BGS)	(m AMSL)	Base	HWL	Dewater	(m)	R_o	L	K = $3.3x10^{-5}$ m/s
AA1	357.7	3.6	354.1	**348.9**	**354.1**	**353.5**	0.6	18.3	9.2	246,306
BB1	358.4	3.8	354.7	**348.9**	**354.7**	**353.3**	1.4	32.1	16.1	345,467
BB2	357.6	3.0	354.7	**348.9**	**354.7**	**353.1**	1.6	35.6	17.8	352,522
BB3	357.3	2.6	354.7	**348.9**	**354.7**	**353.1**	1.6	35.6	17.8	352,522
BB4	358.5	4.0	354.5	**348.9**	**354.5**	**353.8**	0.7	20.1	10.0	280,502
CC1	355.0	2.1	352.9	**348.9**	**352.9**	**350.6**	2.3	47.6	23.8	222,750
CC2	356.5	3.6	352.9	**348.9**	**352.9**	**351.3**	1.6	35.6	17.8	225,614
CC3	358.0	3.8	354.1	**348.9**	**354.1**	**353.5**	0.7	18.3	9.2	246,306

AVERAGE = 283,999

MAXIMUM = 352,522